Epidemiology, Socio-demographic Determinants and Outcomes of Paediatric Facial and Dental Injuries in Scotland

Ousama Hadi Rhouma

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Glasgow Dental School
College of Medical, Veterinary and Life Sciences

University of Glasgow

Executive Summary

Facial injury is less common in childhood than adulthood. However, it is still a significant cause of morbidity and presentation in hospital emergency departments. The pattern, time trends, and key socio-demographic determinants of facial injuries in Scottish adults admitted to hospital have previously been reported but this is not the case in the paediatric population and the question of whether such injuries are equally distributed across all socio-economic groups has not been answered. In contrast to the epidemiology of facial injuries in the paediatric population, traumatic dental injuries in children and adolescents have become one of the most frequent forms of treatment in dental practice. This suggests that traumatic dental injuries are common in childhood and are a significant cause of morbidity and presentation in hospital emergency departments. The relationship between socio-economic circumstances and the commonest dental disease (dental caries) in Scotland is well established and children resident in the most deprived areas experience more dental disease. However, this relationship with regard to dental injuries in Scotland has not yet been established. In the same way, many answers to questions regarding the sequelae and prognosis of pulpal and endodontic treatment among traumatised teeth remain unclear. Furthermore, numerous studies have been published examining the long term variables that might have an effect on treatment outcomes of avulsed teeth, but none have yet been able to estimate the long term prognosis of avulsed and replanted teeth.

Two studies presented in this thesis are largely the result of population based studies investigating the epidemiology of facial and dental injuries in relation to individual demographics. An additional two studies explore the occurrence of paediatric dental trauma and its general treatment outcomes with a specific focus on estimation of the long term prognosis of avulsed and replanted teeth.

To establish the epidemiology of paediatric facial injuries in children and adolescents requiring in-patient hospital admission in Scotland and to report the pattern, time trends, and key socio-demographic determinants of paediatric facial injury in Scotland, a descriptive epidemiological population-based study of the incidence of facial injuries in Scotland (2001-2009) was undertaken. Poisson regression models were employed to assess trends. There were 45,388 (4.7 per 1000 population) facial injury cases registered (2001-2009). 60% of injuries were due to non-intentional causes, 15% to motor vehicle incidents, and 9% to assault. 4.5% were alcohol related. The incidence decreased over time from 5.5/1000 in 2001 to 4.0/1000 in 2009. The risk ratio (RR) for males was 1.98 times greater than females ($p < 0.001$). RR varied significantly between Health Board areas from 0.68 (Dumfries and Galloway) to 1.76 (Grampian) ($p < 0.001$). There was a significant association between facial injury and deprivation ($p<0.001$); SIMD 1 (most deprived) had the highest incidence (6.3 per 1000 population; RR =1.89). The findings of this study provide evidence of a continuing increase in the burden of facial injuries in males especially for those who are living in areas of social deprivation, and in certain geographical areas of Scotland.

A population-based investigation was undertaken to investigate the pattern and time trends of dental injuries and their socio-demographic determinants among primary one (P1) children in Scotland. Records of Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) and National Dental Inspection Programme (NDIP) for the period 1993 to 2007 were retrieved from the Dental Health Services Research unit - Dundee. Annual incidences of dental injuries were calculated by age, gender, Health Board and DEPCAT (Carstairs deprivation categories). 68,354 P1 children were examined and only 405 (0.6%) had suffered dental injuries (5.9 per 1000 population). There was a significant decrease in incidence over time (1993 figures were three times greater than 2007). Virtually the same incidence rates were recorded for the two genders. However incidence varied significantly between Health Boards ($p<0.001$); the highest rate being reported in Dumfries (14.2 per 1000 population), which was 11 times greater than Ayrshire (1.3 per 1000 population).

There was no significant association between risk of dental injuries and deprivation; in DEPCAT 1 (most affluent) the incidence rate was 6.4 per 1000 population, while in DEPCAT 7 (most deprived) the incidence rate was 5.7 per 1000 population. The findings of this study provide evidence that the incidence of dental injuries had significantly decreased between 1993 and 2007; gender and deprivation level had no effect on the incidence and risk of dental injuries.

A retrospective investigation was undertaken to study the sequelae of non-surgical root canal treatment in traumatised anterior permanent teeth of patients referred to a secondary referral centre. The department dental trauma database was used to randomly identify patients who had sustained dental trauma to their permanent anterior teeth between 1994 and 2008 which required pulpal intervention. A data extraction form was designed and completed for each tooth, and then the data was transcribed and processed. The association between treatment outcomes and clinical variables was studied. 100 permanent anterior teeth (72 patients) were studied. Dental trauma was frequent in the age group 9-11yrs (53.9%). Upper central incisors were the most common teeth involved (43.8%). The male: female ratio was 2:1 with an average age at the time of trauma of 10.31 yrs (SD 2.16 yrs). Home and immediate home environs were the commonest location (18%) while falls (34.8%) and injuries during sport/play (34.8%) were the commonest causes. The commonest injuries in this randomly selected group were enamel-dentine fracture with pulp exposure (34.8%) and avulsion (28%). 66.3% received a first treatment intervention less than 24 hours following the injury. Root canal treatment was the most frequent treatment provided, especially for dental avulsion cases (100%). Treatment outcomes were split into three categories: Success (53.4%); Short-term success but long-term failure (35.6%); and Failure (11%). Significantly fewer failures occurred with: developing roots compared to completed roots ($P=0.05$); a good quality temporary filling ($P<0.003$); no mobility ($P<0.001$); and less than one hour extra alveolar dry time ($P=0.02$). No significance was reached with regard to: condition of root canal ($P=0.095$); extra alveolar time (EAT) ($P=0.191$); and type of storage medium ($P=0.43$).

To assess and identify early clinical variables that are most predictive of treatment outcomes for avulsed and replanted permanent anterior teeth and to develop a model that will allow estimation of treatment outcome based on these variables, a retrospective study was designed and undertaken, where the dental trauma database was used to randomly identify patients who had sustained dental trauma on their permanent teeth leading to avulsion between 1998 and 2007. A data extraction form was designed and completed for each tooth. Demographic, diagnostic and treatment information recorded in the patient's records, in addition to radiographs, were viewed and then transcribed and processed. The significance for each early clinical variable was assessed using a univariate logistic regression model. Only significant variables ($P \leq 0.05$) were considered eligible for the prediction model and a c-index was then constructed for their respective predictive power. 213 patients who had received treatment for avulsed and replanted teeth between 1998 and 2007 were studied and only 105 fulfilled the criteria for evaluation. Two models ('at first visit' and 'at initial treatment visits') were produced with a total of five variables holding statistical significance and the greatest predictive power ($P \leq 0.05$, high c-index): patient age ($P \leq 0.001$, c = 0.80); stage of root formation ($P \leq 0.001$, c = 0.76); storage medium ($P \leq 0.047$, c = 0.58); tooth mobility after dressing ($P \leq 0.001$, c = 0.70); and tooth mobility after splinting ($P = 0.03$, c = 0.70) (0.5 = no predictive power, 1.0 = perfect prediction). These underwent multivariate analysis and the final models had high predictive abilities (c-index of 0.80 and 0.74). These findings provide an indication that patient age; stage of root formation; storage medium; tooth mobility after dressing and tooth mobility after splinting were the early clinical variables that were most predictive of treatment outcome. These models will enable clinicians to estimate the long term prognosis of avulsed and replanted teeth and will make it easier to plan further treatment with a realistic view of outcome at an early stage.

To conclude, this thesis has made contributions in several areas. The descriptive elements have described the 'recent' trends in facial and dental injuries among the paediatric population across Scotland in relation to age, gender, aetiology, socio-economic circumstances and geographic region. The socio-economic analysis has improved the understanding of the extent of socio-demographic trends in paediatric dental and facial injuries in Scotland. The findings of these studies, having been described, will become a baseline reference for the recent burden of dental and facial injury in Scotland with relation to socio-demographic determinants. The retrospective descriptive analysis of dental trauma and especially dental avulsion will enable clinicians to identify and determine the clinical variables that are the most predictive of treatment outcomes and permit the development of models that will enable the prediction of outcomes for future replanted avulsed teeth. These models will make it easier to plan for further treatment with a realistic view of outcome at an early stage.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this thesis is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature *O.Rhouma*

Printed name Ousama Rhouma

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Abbreviations

AAPD	American Association of Paediatric Dentistry
DEPCAT	Carstairs deprivation categories
CADO	Committee of Chief Administrative Dental Officers
CDS	Community Dental Service
CDPH	Consultants in Dental Public Health Group
ED#	Enamel dentine fracture
ED#P	Enamel dentine fracture with pulp exposure
EADT	Extra Alveolar Dry Time
EAT	Extra Alveolar Time
#	Fracture
GROS	General Register Office for Scotland
GDHS	Glasgow Dental Hospital and School
GI	Glass Ionomer
HBSS	Hanks Balanced Salt Solution
ISD	Information Services Division in Scotland
IADT	International Association of Dental Traumatology
ICD	International classification of diseases
ICD-10	International classification of diseases (facial injuries)
<	Less than
MTA	Mineral Trioxide Aggregate
>	More than
MVA	Motor Vehicle Accidents
NDIP	National Dental Inspection Programme
NHS	National Health Service
NS-$Ca(OH)_2$	Non- Setting calcium hydroxide
NSS	National Services Scotland
NSRCT	Non-Surgical Root Canal Treatment
NIMDM	Northern Ireland Multiple Deprivation Measure
OR	Odds Ratio
Pop^{n}	Population
RCTs	Randomised Controlled Trials
RR	Rate Ratio
RCT	Root Canal Treatment
SDECC	Scottish Dental Epidemiology Coordinating Committee
SHBDEP	Scottish Health Boards' Dental Epidemiological Programme
SIMD	Scottish Index of Multiple Deprivation
SID	Scottish Indices of Deprivation
SMR	Scottish Morbidity Records
SMR01	Scottish Morbidity Records 01 (in-patient)
TF	Temporary Filling
UK	United Kingdom
WIMD	Wales Index of Multiple Deprivation
WHO	World Health Organisation's

List of Publications

O. Rhouma, F. McCord, R. Welbury. (2010). Treatment outcomes in traumatised permanent anterior teeth requiring pulp treatment. ***European Archives of Paediatric Dentistry*.** Abstracts of EAPD Congress 2010: pp. 46**.**

O. Rhouma, A. McMahon, R. Welbury. (2011). Effects of clinical variables on the outcome of avulsed and replanted teeth: prognostic models for assessment. ***International Journal of Paediatric Dentistry***, 21 (Suppl. 1): pp 174.

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Chapter I - Thesis Introduction, Aims and Overview

1.1 General Introduction to Thesis

This thesis was undertaken in the area of paediatric dentistry at the Dental School at the University of Glasgow. Specifically it is examining paediatric facial and dental injuries from a number of new perspectives.

In Scotland there is more than one data source that can be used for the description of paediatric injuries. These sources have been targeted in order to describe the patterns and trends of subjects who have sustained facial and dental injuries. Scottish Morbidity records for all hospital in-patient care were retrieved from the Information Services Division in Scotland (ISD), Records of Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) and National Dental Inspection Programme (NDIP) were retrieved from the Scottish Dental Epidemiology Coordinating Committee (SDECC), and the dental trauma database at a secondary referral centre (Glasgow Dental Hospital and School 'GDHS') was used to retrieve data concerning all referred traumatic tooth injuries and specifically avulsion injuries.

1.2 Paediatric facial injuries

Injury is the leading cause of death in children. Serious maxillofacial injuries occur less frequently in children compared to adults but nevertheless these injuries require significant in-patient care and treatment. Treatment in children compared to adults is also sometimes different because of the needs of the growing facial skeleton in children. The term facial injury refers to any injury to the face or upper and lower jaw bones and includes injuries to the soft tissue (skin), underlying skeleton, neck, nasal area (sinuses), orbital socket, or oral lining, as well as the teeth and dental structures. Frequently these types of injuries are called maxillofacial injuries, and they can occur in isolation or in combination with other injuries. Facial trauma is often recognized by swelling or lacerations. Signs of broken bones include bruising around the eyes, widening of the distance between the eyes, movement of the upper jaw when the head is stabilized, abnormal sensations on the face, and bleeding from the nose, mouth, or ear.

Numerous studies have been published internationally on the epidemiology of facial injury in the paediatric population and they report a prevalence of 1% to 15% (Haug and Foss 2000, Levin et al., 2010, Kidd et al., 2010). This suggests that although facial injury is less common in childhood than adulthood it is still a significant cause of morbidity and presentation to hospital emergency departments.

Facial injury can encompass minor injuries that heal without evidence of the injury to disfigurement that lasts a lifetime. The face is critical in communicating with others, so it is vitally important to get the best and most appropriate treatment possible. The causes of facial injury in childhood would appear to be multifactorial with mechanisms of injury including falls, interpersonal violence, motor vehicle incidents and other non-intentional causes.

In Scotland the socio-demographic determinants of facial injuries in the paediatric population have not previously been reported and the question of whether such injuries are equally distributed across all socio-economic groups has not been answered.

1.3 Paediatric dental injuries

In contrast with the epidemiology of facial injury in the paediatric population, dental injuries in children and adolescents have become one of the more frequent forms of treatment in dental practice. This suggests that traumatic dental injuries are common in childhood and are a significant cause of morbidity and presentation to hospital emergency departments. Several studies have reported that the prevalence of these injures has increased over the past few decades. In contrast to many other traumatic injuries, dental injuries are mostly irreversible and thus treatment will be likely to continue for the rest of the patient's life (Glendor et al., 2001, Andreasen et al., 2007, Glendor 2008), and may have an impact on children's quality of life, especially as the majority of dental injuries involve the anterior teeth (Rock et al., 1974, Stalhane and Hedegard et al., 1975, Todd and Dodd 1985, Jackson et al., 2006, Andreasen et al., 2007). The consequences of traumatic dental injury can vary from complete recovery to the loss of the tooth. At the same time dental Injuries to children's teeth can be very distressing for children as well as their parents.

A number of activities put children at risk for dental injury, such as contact sports, playing, and running or cycling, especially during the first years of childhood. This reaches a peak during the school years when accidents in the school playground are common. Traumatic dental injuries related to interpersonal violence tend to be more common in older individuals.

The relationship between socio-economic circumstances and dental caries in Scotland is well established. Those children resident in the most deprived areas experience more dental caries. There is a sequential rise in the number of decayed and missing teeth when moving from the more affluent to the most deprived areas. Five year old children from the most deprived areas, have more than 3 times the amount of dental disease experienced by those children living in the most affluent postcode sectors (Sweeney et al., 1999). This information about caries contrasts with the relationship between traumatic dental injuries and socio-economic circumstances which to date in Scotland has not yet been studied and any relationship established.

1.4 Aims of the study

The overall aims of this thesis are:

1. To describe, analyse and report the epidemiology, pattern, time trends and key socio-demographic determinants in children and adolescents who have suffered facial injury requiring in-patient care.

2. To describe, analyse and report the epidemiology, pattern and time trends of dental injuries and their socio-demographic determinants among primary one (P1) children in Scotland.

3. To examine the occurrence of paediatric dental injuries and to investigate the sequelae of pulpal and non-surgical root canal treatment in traumatised anterior permanent teeth of patients referred to a secondary referral centre.

4. To identify and determine the early clinical variables that were most predictive of treatment outcome of avulsed and replanted permanent anterior teeth referred to a secondary referral centre and to develop model(s) that will enable prediction of outcomes for future replanted avulsed teeth based on these variables.

1.5 Outline of this Thesis

This thesis describes the epidemiology of facial and dental injuries among the Scottish paediatric population with a focus on the socio-demographic determinants in addition to the outcome of dental trauma before exclusively concentrating on replanted avulsed teeth treated at Glasgow Dental Hospital and School (GDHS).

In this first chapter the context for the study has been outlined. **Chapter II** of the thesis is a review of the literature in the fields of the epidemiology of paediatric facial injuries and dental injuries, the relationship with socio-economic circumstances and inequalities, in addition to the epidemiological aspects of dental avulsion, especially among children and adolescents. It will also discuss the current debates, issues and knowledge gaps.**Chapter III** illustrates the epidemiology of paediatric facial injuries in children and adolescents requiring in-patient hospital admission in Scotland and shows the pattern, time trends, and key socio-demographic determinants of paediatric facial injuries that required in-patient hospital admission in Scotland between 2001 and 2009. This chapter identifies the demographics of paediatric facial injury in Scotland and explores the characteristics and trends of these injuries over time, at the same time assessing the differences in socio-demographics that exist between facial injury cases and documenting the length and trends of hospital stay of the subject cases over the study period. Additionally, this chapter reports the prevalence of facial injuries associated with interpersonal violence, motor vehicle incidents, and other non-intentional events and shows whether alcohol consumption was an associated factor with facial injury in this group of the population.

Chapter IV focuses on the epidemiology of paediatric dental trauma in 5 year olds (Primary one) in Scotland between 1993 and 2007 and explores the pattern and time trends of these injuries and their socio-demographic determinants among this group of population. This chapter identifies the demographics of traumatic dental injuries in Scotland and describes the characteristics and trends of traumatic dental injuries over time in Scotland. At the same time it demonstrates whether differences in socio-demographics exist between traumatic dental injury cases.

Chapter V examines the occurrence of dental trauma and investigates, retrospectively, the sequelae of non-surgical root canal treatment in young traumatised anterior permanent teeth treated at Glasgow Dental Hospital and School (GDHS) between 1994 and 2008. This chapter evaluates the incidence of traumatic dental injuries and their various etiologic factors in relation to the age and gender of the patient, type and number of teeth involved. Also it assesses and determines the magnitude of the factors associated with the outcomes of treatment of traumatised teeth.

Chapter VI explores and determines the clinical variables that were most predictive of treatment outcomes of replanted avulsed teeth referred to and treated at Glasgow Dental Hospital and School (GDHS) between 1998 and 2007. This chapter illuminates the association between early clinical variables and treatment outcome of avulsed and replanted anterior teeth and applies contemporary statistical methods to determine the magnitude of these variables on the outcomes and develops models that will allow prediction of treatment outcomes based on these variables.

In **Chapter VII** there is a general discussion around the interest, importance, originality, achievements, contributions, findings, strengths and limitations of the thesis and concludes with recommendations for future research projects that could inform and complement this thesis.

Final summary conclusions and general recommendations for practice are detailed in **Chapter VIII**. This thesis ended with References and Appendices cited in the thesis.

Chapter II - Review of the Literature

2.1 Introduction

This chapter aims to review the literature in the fields of the epidemiology of paediatric facial injuries and dental trauma, the relationship with socio-economic circumstances and inequalities, in addition to the epidemiological aspects of dental avulsion especially among children and adolescents. It will also discuss the current debates, issues and knowledge gaps. This exploration was important to inform and underpin the research aims.

The literature review is divided into sections each designed to add a specific dimension in which to underpin the thesis. Section 2.2 starts with a discussion of some key definitions. It then addresses the epidemiology of facial injuries, deprivation and socio-economic status, and their relationships with the risk of facial injuries. At the end of this section the measures of deprivation will be reviewed. Section 2.3 will review the scientific publications relevant to dental trauma and its management and outcomes, aiming to provide a better understanding of current treatment philosophies in dental trauma. This review is intended to focus on pulpal/endodontic therapy resulting from dental trauma. The final section (2.4) aims to provide a better understanding and background to the treatment of dental avulsion by reviewing the relevant literature on this topic, thereby identifying a logical approach to this clinical issue.

2.2 Facial injury in children and adolescents

2.2.1 Introduction

Several recent studies (Kidd et al., 2010, Levin et al., 2010, Thoren et al., 2010) have been published internationally on the epidemiology of facial injuries in paediatric populations and they report a low prevalence of these injuries among this age group. This suggests that although facial injury is less common in childhood than adulthood it is still a significant cause of morbidity and presentation to hospital emergency departments. The causes of facial injury in childhood would appear to be multifactorial with mechanisms of injury including falls, interpersonal violence, motor vehicle incidents and other non-intentional causes. More recently the pattern, magnitude, time trends, and key socio-demographic determinants of facial injuries in Scottish adults admitted to hospital have been reported. There was a clear and significant association with socio-economic deprivation. However, the socio-demographic determinants of facial injuries in the paediatric population in Scotland have not previously been reported and the question of whether such injuries are equally distributed across all socio-economic groups has not been answered.

2.2.2 Search strategy

The search included:

1. Electronic journals and databases, such as PUBMED, Ovid, science direct, and others, including the web of science together with some electronic search engines such as Endnote online search mode and Google. Using different searching keywords such as: Facial, maxillofacial, oro-dental, oral, trauma, traumatic, injury, injuries, laceration, children, adolescents, paediatric, epidemiology, causes, sequel, prevalence, incidence, trends, patterns, and demographics. Additionally the words deprivation and inequality were included. These keywords were assembled or arranged and put together to form a search string using some Boolean operators such as AND, NOT, OR.

2. Hand search of textbooks, journals or articles on shelves of Glasgow dental hospital and school library. In addition to screening and follow-up of different references quoted in individual papers.

3. Access to various websites.

The range of searching was not limited to publication date or any source of information. At the same time, it depended on the availability of database source. This part of the literature review starts with a discussion of some key definitions. It then addresses the epidemiology of facial injuries, deprivation and socio-economic status, and their relationships with the risk of facial injuries. Finally measures of deprivation are reviewed.

2.2.3 Definitions

2.2.3.1 Facial trauma

There are a number of definitions of injury and what constitutes an injury. On the whole, injury refers to damage to the body because of an exchange of energy usually in a single episode. In general, the common definition for injury used by injury researchers is tissue or body damage or loss of function of a body part that occurs because of an abnormal energy exchange between a person and an energy agent (Conroy and Sciortino 1997). Alternatively, an injury is the result of a single traumatic event where the harm or hurt is immediately apparent, for example a cut resulting from an accident with a knife, or burns resulting from an acid splash (Conroy and Sciortino 1997). Consequently, facial trauma means any injury to the face or upper and lower jaw bones. It also includes injuries to the soft tissue, underlying skeleton, neck, nasal area, orbital socket, or oral lining, as well as the teeth and dental structures. Frequently these types of injuries are called maxillofacial injury, which can occur in isolation or in combination with other injuries elsewhere. It is often recognized by skin lacerations; bruising around the eyes; widening of the distance between the eyes (which may indicate injury to the bones between the eye sockets); and movement of the maxilla when the head is stabilized (which may indicate a fracture in this area). Bones and teeth may be stressed to the extent that they fracture or dislocate and abnormal sensations may be elicited on the cheek (Pedlar and Frame 2007).

2.2.3.2 Children

The definition of children (childhood) may seem reasonably straight forward. In a human this is the time between the stages of birth and puberty. In many countries, there is an age of majority (adulthood) when childhood officially ends and a person legally becomes an adult. The age ranges anywhere from 13 to 21, with 18 being the most common.

2.2.3.3 Deprivation

In contrast to poverty which is often viewed in terms of being short of money or material possessions to get by (Atkinson 1998), deprivation is a wider concept than poverty. Deprivation is usually taken to refer to problems caused by a general lack of resources and opportunities not just money (Townsend 1987). In 1987, Townsend argued that people can be said to be deprived if they lack the types of diet; clothing; housing; household facilities and fuel; environmental; educational; working and social conditions; activities and facilities which are customary (Townsend 1987).

2.2.4 Epidemiology of facial injury

2.2.4.1 Type and severity of facial injury

Several studies of facial injuries have been carried out worldwide, where the nature and the type of injuries have been studied, especially among the adult population. It has been shown in several studies of maxillofacial trauma that injuries of the maxillofacial region occur less commonly in children than in adults (Hutchison et al., 1998) and they are more often minimally displaced. This might be because a thicker layer of soft tissues covers the more elastic bones and flexible bone suture lines of the child. At the same time, Paediatric facial trauma differs from adult injury because the face is not fully formed and future growth will be a factor in how the child heals and recovers. Soft tissue injuries are more common in children who have sustained facial trauma, particularly younger children (Hogg and Horswell 2006), but other studies have shown that injuries tend to be, in general, less severe in young children than in older children (Haug and Foss 2000).

2.2.4.2 Prevalence of facial injuries

It has been described in the literature in some studies that the prevalence of facial injuries in the general population could reach up to 35 % of recruited cases (Gassner et al., 1999). In contrast, an American study suggested that the paediatric population sustains 1% to 14.7% of all facial injuries (Haug and Foss 2000). Similarly, some other studies reported a lower prevalence of facial injuries in children (2% - 5%) (Kidd et al., 2010, Levin et al., 2010).

Overall, this indicates that the prevalence of facial injuries is a common cause for presentation to emergency departments for children. At the same time, facial injury is a common leading cause of morbidity and mortality in children. These findings have been based on both retrospective studies where facial trauma has been noted and prospective studies where a population has been followed for a particular time period (Thoren et al., 1997, Hutchison et al., 1998, Zerfowski and Bremerich 1998, Gassner et al., 1999, Vanderas and Papagiannoulis 1999, Hogg et al., 2000, Naidoo 2000, Marcenes and Murray 2001, Shaikh and Worrall 2002, Barker et al., 2003, da Silva et al., 2004, Gassner et al., 2004, Adeyemo et al., 2005, Zimmermann et al., 2005, Hogg and Horswell 2006, Islam et al., 2006, Rahman et al., 2007, Imahara et al., 2008, Eggensperger Wymann et al., 2008, Lin et al., 2008, Vyas et al., 2008, Al-Malik 2009, Lieger et al., 2009, Kidd et al., 2010, Levin et al., 2010, Thoren et al., 2010).

More recently a number of researchers have questioned the prevalence of facial injuries in children. A retrospective study carried out over one year in South East of Scotland has shown that children with facial injury accounted for only approximately 2% among 623 patients who attended with a facial injury (Kidd et al., 2010). Another retrospective study in Tel-Aviv investigating maxillofacial trauma as a public health problem showed that only 4.7% of recruited cases were children under 17 year old (Levin et al., 2010) Similarly in Finland it was reported that only 10.7% among 389 patients with maxillofacial trauma were children under 19 years old (Thoren et al., 2010). These recent studies suggest that the low incidence of facial trauma among children still holds true and are equivalent to levels reported in the review in

Nigeria in 2005 which showed that the peak ages of incidence of maxillofacial injuries were 21-30 years followed by 31-40 years (Adeyemo et al., 2005).

The above results are however in contrast to those studies which have shown a high prevalence of facial trauma in children. Gassner and colleagues in 1999 undertook a retrospective study which recruited around 6000 patients in Austria and noted that of 6000 that presented with facial injury over a 6 year period, about 37.4% (2245 patients) were children under 19 years old (Gassner et al., 1999). In the same manner, da Silva et al., reported a high incidence of facial injury in his research which was carried out in Brazil in 2004 and which showed about 37.65% (128/340 patients) were patients under 20 years (da Silva et al., 2004).

2.2.4.3 Causes of facial injury

The common cause of facial injury in childhood would appear to be multifactorial and multifaceted with a variety of aetiologies ranging from falls and interpersonal violence to motor vehicle accidents (MVA) and sporting accidents. All together, the frequency of any specific aetiology might vary within geographic regions and might be dependent upon life style, population density, characteristics and socio-economic situation. While MVA and interpersonal violence are implicated in the vast number of adult facial trauma, the aetiologies in children are somewhat different where falls during daily activities would appear to be the most common cause (Hogg et al., 2000, Shaikh and Worrall 2002, Barker et al., 2003, da Silva et al., 2004, Zimmermann et al., 2005, Rahman et al., 2007, Eggensperger Wymann et al., 2008, Lin et al., 2008, Al-Malik 2009, Lieger et al., 2009, Kidd et al., 2010, Thoren et al., 2010). All these studies have reported that falls are either the first or the second most common cause of facial injuries. In addition, interpersonal violence (assaults) has been documented as one of the common causes of facial injuries in children (Zerfowski and Bremerich 1998, Shaikh and Worrall 2002, Imahara et al., 2008). Additionally some other studies have implicated MVA as the leading cause of facial injuries (Thoren et al., 1997, Hogg et al., 2000, da Silva et al., 2004, Adeyemo et al., 2005, Rahman et al., 2007, Eggensperger Wymann et al., 2008, Imahara et al., 2008, Lin et al., 2008).

2.2.4.4 Gender differences

There is an overwhelming male predominance in reported studies with regard to facial injuries. Most of the studies confirm at least a 1.3:1 male to female ratio as demonstrated in Table 2. 1.

Table 2. 1 Summary of some reviewed studies

Study ref.	Location	Patients age (yrs)	Male/female ratio	Aetiology 1st major cause /2nd major cause	Facial injury among Children %/common age	Facial injury common age /%	Study period/No .of patients
(Kidd et al., 2010)	UK	2.4-7.5	2:1	Falls/#	2%/2.4-7.5	3-6/#	12 months/623
(Thoren et al., 2010)	Finland	10-84	3.8:1	Assault/Falls	10.7%/0-19	20-29/#	2 years/389
(Levin et al., 2010)	Tel-Aviv	#	2.9:1	Falls/MVA	2.4%/0-17	>18/4.5%	3 years/1713
(Al-Malik et al., 2009)	Saudi	1-17	2.4:1	Falls/#	#/9-11	#/#	12 months/112
(Lieger et al., 2009)	Switzerland	1-93	2.1:1	Falls/Sport	#/#	#/#	12 months/273
(Eggensperger et al., 2008)	Switzerland	0-16	1.4:1	Falls/MVA	#/#	>6/52%	3 years/291
(Vyas et al., 2008)	USA	0-17	2.5:1	Falls/Assault	#/#	15-17/55.9%	6years/10359
(Lin et al., 2008)	Tel-Aviv	0->59	3:1	Falls/MVA	28.7%/0-18	19-28/24.7%	4 years/ 111010
(Imahara et al., 2008)	USA	0-18	2.1:1	MVA/Assault	#/#	15-18/#	4 years/ 277008
(Rahman et al., 2007)	Malaysia	0-16	2.9:1	MVA/Falls	#/#	11-16/49.5%	3 years/521
(Islam et al., 2006)	UK	0-12	1.6:1	Play outside	#/#	4-6/44%	9 months/100
(Zimmermann et al., 2005)	USA	#	1.1:1 to 8.5:1	Falls/Sport	15%/school ages	#/#	#/#
(Adeyemo et al., 2005)	Nigeria	#	3.3:1	MVA/Assault	Low%/>10	21-30/#	33 years
(Da Silva et al., 2004)	Brazil	0-80	3.6:1	Falls/MVA	37.65%/1-20	11-20/25%	12 months/340
(Gassner et al., 2004)	Austria	0->15	1.7:1	Play/Sport	#/#	3-11/50%	9 years/ 3385
(Erol et al., 2004)	Turkey	0-<60	2.4:1	MVA/Falls	46.7%/0-19	0-10/27.6	20 years/2901
(Barker et al., 2003)	Australia	0-79	#	Falls/ Play outside	#/1-4 &10-14	15-24/19.6%	4 years/17886
(Shaikh and Worrall, 2002)	UK	1-18	2.3:1	Falls/Assault	#/#	1-10/65.5%	3 years/276
(Hogg et al., 2000)	Canada	1-99	3:1	MVA/falls	#/15-19	25-34/#	5 years/2969
(Vanderas and Papagiannoulis, 1999)	Greece	8-10	1.7:1	#	45.2%/10-12	25%/11	2 years/199
(Gassner et al., 1999)	Austria	0-89	1.9:1	Assault/MVA	37.4%/#	#/#	6 years/6000
(Zerfowski and Bremerich, 1998)	Germany	0->19	1.7:1	Assault	#/#	3-5/#	3 years/1385
(Thoren et al., 1997)	Finland	1->16	1.3:1	Cycling/MVA	#/#	10-12/31%	11 years/101

Not specified or not mentioned

2.2.4.5 Age distribution

In the literature there is no uniformity of agreement as to what age group is considered as paediatric. Some studies have reported that up to age 20 years could considered as a paediatric (da Silva et al., 2004) while others consider 18 or 19 years of age is the maximum age of paediatrics (Erol et al., 2004, Lin et al., 2008, Levin et al., 2010, Thoren et al., 2010), and others reported up to age 16 years (Thoren et al., 1997, Vanderas and Papagiannoulis, 1999, Gassner et al., 2004, Rahman et al., 2007, Eggensperger Wymann et al., 2008, Al-Malik 2009). This often makes comparison of findings between studies difficult. However there appears to be agreement that the incidence of facial trauma, especially facial fractures increases with age. The incidence rises from when children begin school until puberty and adolescence. The site and the cause of injury would also appear to be related to age.

In the studies reviewed, the variation in findings regarding facial injuries and age is demonstrated in Table 2. 1. One study reported that the most common age to sustain facial injuries among children is less than 6 years (52%) (Eggensperger Wymann et al., 2008), while another in the same year reported that 15-17 years old was the commonest age (55.9%) (Vyas et al., 2008). Alternatively another study conducted at a different time and in a different location reported that 1-10 years of age is the commonest age (65.5%) to sustain facial injuries in children (Shaikh and Worrall 2002).

2.2.5 Socio-economic status and deprivation level

The literature identifies that injuries are the major cause of worldwide morbidity among children and adolescents especially in developed countries. However there is lack of agreement on the relationship between socio-economic status and the risk of injuries to children and whether injuries are equally distributed across all socio-economic groups. In light of this, an exploration on how to measure socio-economic status and it is relationship to injury is important.

2.2.5.1 Measures of deprivation and socio-economic status

The relationship of socio-economic status with injuries has been made difficult by inconsistencies in the measurement of socio-economic status. Traditionally classifications of socio-economic status were based on straightforward written responses to a request for a description of a parent's job by simply asking whether the parents are working. Other classifications went further and tried to measure the family affluence by asking questions about material wealth of the family using some direct questions such as how many cars the family owned or whether all family members had their own bedroom or not.

It is not easy to measure poverty directly (Atkinson 1985, Townsend 1987), but it is possible to obtain measures of deprivation where it is more easy to measure material deprivation related to diet, health, clothing, housing, household facilities, environment and work (Townsend 1987).

2.2.5.2 United Kingdom indices of multiple deprivation and socio-economic status

More recently in the United Kingdom (UK) there has been more than one method to measure deprivation and socio-economic status. Indeed some of these indices were already being used to assess socio-economic status in relation to injury. These different indices have much in common but vary in the data used in each index because of a difference in availability of data in each area. At the same time, there is no one index that can be used for the whole UK. All in all, these indices are not directly comparable.

2.2.5.2.1 Townsend Index

In England and some parts of Wales the Townsend Index was used to determine the level of deprivation. The Townsend Index was developed by Townsend et al., in the mid-1980's to provide a material measure of deprivation. Using data from the 1981 census it was first used in 1988 by Townsend et al., (Townsend et al., 1988). The index is based on four different variables: households not owner-occupied; access to a car; household overcrowding; and unemployment rates. Each of which must be divided by the appropriate count of households or persons to obtain a percentage. The higher the Townsend Index score, the more and greater the deprivation. Hippisley-Cox in 2002 and his colleges used this index to determine the relationship between morbidity and deprivation for different levels of injury severity and for different injury mechanisms for children aged 0-14 years (Hippisley-Cox et al., 2002). Lyons et al. used the same index in 2003 to compare hospital admission rates for all causes and specifically causes of injury in children and the elderly by a measure of economic deprivation (Lyons et al., 2003).

2.2.5.2.2 Jarman Index

The Jarman Index (Jarman 1983) is another index measuring socio-economic status and level of deprivation In England. This index was originally developed by Jarman in 1983 to help measure the demand on the primary health care services, specifically to measure pressure on the services of general medical practitioners. The Jarman index is often used as an indicator of deprivation, although it is not designed to be indicator of material deprivation, unemployment or poverty, but to highlight areas where there may potentially be a higher demand for primary health care services. A high Jarman score may therefore indicate a high demand for primary health care services whilst a low score may indicate low demand. It is based on the weight of socio-economic variables taken from the census: unemployment; overcrowding; lone pensioners; single parent family; children aged under five; unskilled manual workers; change of address in previous year; and ethnic minority. In 2001 Marcenes and Murray used this index to assess the level of deprivation among 14 year old schoolchildren in Newham whilst trying to assess the epidemiology of traumatic dental injuries (Marcenes and Murray 2001).

2.2.5.2.3 Wales Index of Multiple Deprivation (WIMD)

In Wales, another index has been used to assess socio-economic status and level of deprivation; it is Wales Index of Multiple Deprivation ‘WIMD 2005’. The initial Welsh Index of Multiple Deprivation was published in August 2000. It is the official measure of deprivation for small areas in Wales and consists of six domains, or factors believed to indicate deprivation: income; employment; health; education; housing; and geographic access to services. In Wrexham in 2004, Mendonca used this index to assess the level of social deprivation in order to find the relationship between social deprivation and incidence of burns in an accidents and emergency setting (Mendonca et al., 2004).

In November 2005, a new, revised WIMD was released. The updated index included an additional domain (Environment). The index is currently updated every three years, with the most recent one published in 2011 (Wales GOV. 2011). Changes include the addition of a Community Safety domain as well as new and amended indicators for some of the existing domains.

The above three indices mentioned are not comparable with one another, nor with those from other UK countries, as they are separate indexes with different indicators.

2.2.5.2.4 Noble Index

In 2001 Mike Noble designed the Noble index to measure and provides detailed information of social deprivation in Northern Ireland. In 2010 the Northern Ireland Statistics and Research Agency updated this index and published the new Northern Ireland Multiple Deprivation Measure (NIMDM-2010) which identifies small area concentrations of multiple deprivation across Northern Ireland. It is made up of a series of distinct types of deprivation (called domains). Each domain consists of a number of indicators that reveal the different aspects of deprivation experienced by individuals living in an area. These domains of deprivation were measured across a range of 43 indicators. As with the new NIMDM 2010, there were seven domains in the Noble 2001 index including: income deprivation; employment deprivation; health deprivation and disability; education; skills and training deprivation; geographical access to services; social environment; and housing stress. With the NIMDM 2005 the first five domains have generally remained the same with some changes to the indicators used and, in the case of education, skills and training deprivation domain, a slight alteration to the structure (basically dividing the domain into two sub-domains concerned with young people and adults respectively). The geographical access to services domain has been renamed proximity to services. In 2005, on the basis of this index, Silversides measured social deprivation in Northern Ireland (Belfast) and compared injury rates in children between the most deprived and least deprived areas, (Silversides et al., 2005).

2.2.5.2.5 Carstairs Deprivation Index

Carstairs Deprivation Index or Carstairs deprivation categories (DEPCAT) was the first index specifically developed for Scotland to measure socio-economic status. It was developed by Carstairs and Morris (Carstairs and Morris, 1991), as an alternative to the Townsend Index of deprivation but unlike Townsend, it avoided using the number of private households as the denominator and also did not use owner-occupied housing tenure as a variable (Carstairs and Morris, 1991; Elliot et al., 2000). Typically these areas are based on postcode sectors of which there are almost 1,000 in Scotland with an average population of around 5,000 (McLoone, 2004). The main source of data about the socio-economic characteristics of each area is the 10 yearly census, which records information about the social and economic characteristics of the resident population living in each area. In the Carstairs index each of these indictors was equally weighted and the final figure equalled the Carstairs score. Generally, these scores have been divided into seven categories based on the summed scores, with DEPCAT 1 representing the most affluent postcode and DEPCAT 7 representing the most deprived postcode. In 1999 Morrison et al. used this index to analyse the socio-economic differentials in deaths from injury in children aged 0-14 years in Scotland (Morrison et al., 1999), and found that children in the lower socio-economic groups seemed to be experiencing progressively increasing relative risks of injury in comparison with those in higher socio-economic groups.

2.2.5.2.6 Scottish Index of Multiple Deprivation

Another index has recently been developed and used in Scotland to assess levels of deprivation. This is the Scottish Index of Multiple Deprivation (SIMD), which has the ability to distinguish the level of deprivation between areas across Scotland. This was achieved by recording the levels of deprivation for small geographic areas (data zones) which were ranked from 1 (most deprived) to 6505 (last deprived), where the level of deprivation in each domain was calculated on the basis of a range of indicators. The overall levels are then calculated on the basis of weighting and combining the individual deprivation domains. The weighting for each domain is based on the relative importance of the domain in measuring multiple deprivation. In addition and before weighting, the domains are standardised by ranking the scores. The ranks then undergo a statistical transformation to avoid high ranks in one domain. The domain weightings used in SIMD 2009, expressed as a percentage of the overall weight are: current income (28%); employment (28%); health (14%); education (14%); geographic access (9%); crime (5%); and housing (2%) (SCOT-GOV. 2010).

The first SIMD was produced and published by the Scottish Executive Office of the Chief Statistician in 2004. It was based on the methodology developed for the Scottish Indices of Deprivation 2003 'SID 2003' (SCOT-GOV. 2003), in collaboration with the Executive; and the Social Disadvantage Research Centre at University of Oxford was enlisted to offer important advice on some of the more technical issues regarding the construction of the indices (SCOT-GOV. 2003). In 2004, SIMD was based on 31 indicators in six domains: current income; employment; housing; health; education; skills and training; and geographic access to services and telecommunications. The SIMD was revised in 2006 and again in 2008. In 2006 a further domain was added to so there were 37 indicators, and seven domains. The domains are:

1. Current Income Domain; containing indicators measuring low income by the proportion of adults and children receiving low income benefits

2. Employment Domain; containing indicators identifying those people who want to work but can't due to unemployment

3. Health Domain; containing indicators that focus on mortality and morbidity

4. Education, Skills and Training Domain; containing indicators that measure lack of progression to higher or further education

5. Housing Domain, containing indicators that measure persons and households which are overcrowded and persons in households without central heating

6. Geographic Access and Telecommunications Domain; containing indicators that measure the use of public transport and the drive time to specific services such as general practitioner, supermarket, primary school, and post office (including public transport travel times for the first time)

7. New Crime Domain, containing indicators linking recorded crime to deprivation

In 2009 (revised 2008) the most updated SIMD was produced and published and combines 38 indicators across 7 domains (Figure 2. 1). SIMD 2009 is an update with improvements on SIMD 2006 and uses the same geographical base as SIMD 2006 and SIMD 2004 of data zones with a number of main changes to domains (SIMD.SCOT-GOV. 2010).

1. Income - working and Child Tax Credit data were included

2. Employment – no change

3. Health – changes to ‘hospital episodes related to alcohol and drug use’

4. Education – small change to (Not in education’ employment or training) NEET indicator

5. Geographic Access – changes to calculation tool

6. Housing – no change

7. Crime – small change to financial year reporting from calendar year

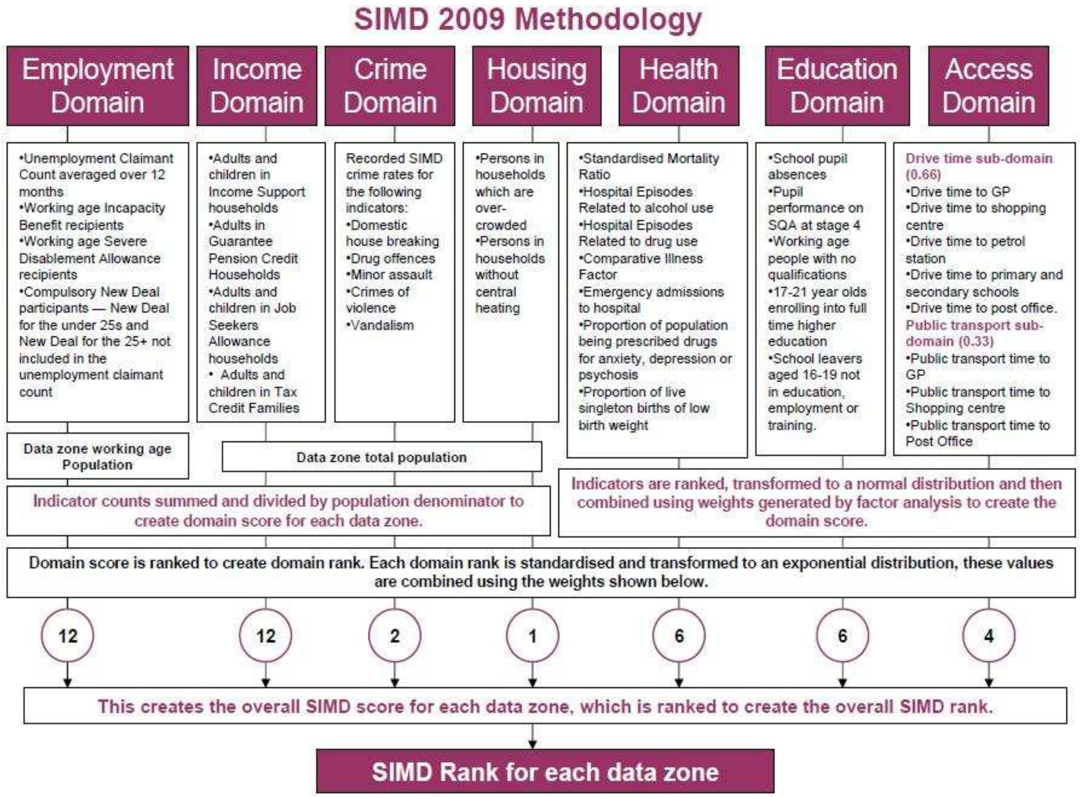


Figure 2. 1 SIMD 2009 methodology
Source:(http://www.scotland.gov.uk/Topics/Statistics/SIMD/MethodologyV isual2009)

Each of the SIMD domains uses the most appropriate and up to date information that was available at the time of compilation. The SIMD 2004 represented information from 2001/2002 for most domains and used 2001 census based population estimates, whereas the majority of the SIMD 2006 data is from 2004/2005 and uses 2004 small area population estimates provided by the General Register Office for Scotland. The 2009 index relies mainly on 2007/2008 data. This should be considered when examining changes over time.

2.3 Dental Trauma

2.3.1 Introduction

Traumatic dental injuries in children and adolescents have become one of the most frequent forms of treatment in dental practice. Numerous studies have reported that the prevalence of these injures has increased over the past few decades. It has been reported that about 35% of school age boys and about

25% of school age girls had sustained traumatic dental injury to their permanent anterior teeth (Anderson and Ravn 1972, Hedegard and Stalhane 1973, Schatz and Joho 1994).

The consequences of traumatic dental injury can vary from complete recovery to the loss of the tooth. Dental trauma is considered to be the most common cause of tooth loss in childhood especially the permanent anterior teeth. If a tooth was so badly fractured or if it was avulsed and no attempt made to reimplant the tooth, then this will lead to loss of the tooth (Todd and Dodd 1985). The common sequelae of dental trauma, especially in anterior teeth, is injury, loss of vitality, or infection of the dental pulp and this will have a major influence on the long-term prognosis of the traumatised teeth (Anderson and Pedersen 1985, Adelek et al., 2007). In these cases, the treatment options could be pulpal therapy or endodontic treatment (Friedman 2002, Robert and Lian 2004).

Pulpal therapy and endodontic therapy have become a common procedures performed in dental practices in the course of prevention or elimination of apical periodontitis (Friedman 2002). Pulp therapy (also referred to as vital pulp therapy) is the treatment of the dental pulp in order to maintain or restore health to the pulp. If the dental pulp is infected or becomes necrotic, endodontic therapy 'root canal treatment' is the only treatment option directed at prevention and elimination of apical periodontitis. Apical periodontitis is a sequel to endodontic infection and manifests itself as the host defence response to microbial challenge emanating from the root canal system and which affects the tissue surrounding the roots of the teeth. At the same time, it is generally accepted that the most favourable prognosis for teeth with an irreversibly necrotic pulp is obtained by providing appropriate endodontic therapy (Cohen et al., 2006, Ørstavik and Ford 2008).

This literature review seeks to review the relevant scientific articles which cover the management and outcomes in dental trauma thereby providing a better understanding of dental trauma. This review is intended to focus on dental trauma and pulpal/endodontic therapy as one of the commonest treatment strategies in managing traumatised teeth.

2.3.2 Search strategy

The search included:

1. Textbooks, journals or articles on shelves of Glasgow dental hospital and school library, in addition to screening and follow-up of different references quoted in individual papers.
2. Electronic journals and database search, including Ovid, PUBMED, MEDLINE, and others, including the web of knowledge together with some electronic search engines such as Endnote online search mode and Google. Using different searching terms and words such as Pulpal therapy outcomes, endodontic treatment outcomes, dental trauma, management of traumatised teeth and assessment of treatment outcomes and others. These terms and words were assembled or arranged and put together to form a search string with using some Boolean operators such as AND, NOT, OR.
3. Access to various websites.

The relevance of any study contained in this review should be considered with relation to the pulpal/endodontic treatment outcomes and/or approaches to improve the treatment outcomes of traumatised permanent teeth. The range of searching was not limited to publication date or any source of information. At the same time, it depended on the availability of database source.

The review starts with a discussion of aspects of the dental pulp in health followed by review of the dental pulp in dental trauma with different aspects such as epidemiology, aetiology, diagnosis and sequelae. The treatment and management of dental trauma with regard to pulpal and endodontic therapy and outcomes are then reviewed.

2.3.3 The dental pulp in health

Tooth pulp is the innermost tissue of the tooth. It forms from the central cells of the dental papilla. Dental pulp is involved in the support, maintenance and continued formation of dentine as the main bodies of odontoblast cells remain along the outer pulpal wall. Equally, dental pulp serves as a source of nutrition for the dentine as the dentine contains no blood supply. Nutrition and blood supply for dentine are supplied via the dentinal tubules and their connection to the odontoblast cell bodies that line the outer pulpal wall. Another function of the pulp is sensory, because the cell bodies associated with the afferent axons in dentinal tubules are located among this layer of odontoblasts. Further, the pulp has a protective function in case the pulp suffers any injury that also involves the odontoblasts. The undifferentiated mesenchymal cells of the pulp can differentiate into fibroblasts, which then create fibres and intercellular substances as well as odontoblasts to create more dentine (tertiary dentine). The pulp also has white blood cells which allow activation of inflammatory and immune responses (James et al., 2002, Bath-Balogh and Fehrencach 2005, Cohen et al., 2006, Nanci 2008, Ørstavik and Ford 2008).

Dental pulp is enclosed within the pulp chamber of the tooth; accordingly pulp chamber shape differs in relation to the shape of the tooth. The pulp has two main divisions; coronal pulp and radicular pulp. Dental pulp is connected to the surrounding periodontal ligament through the apical foramen, which is the opening from the pulp at the apex of the tooth. This opening is surrounded by cementum and allows arteries, veins, lymphatics and nerves to enter and exit the pulp from the periodontal ligament. Communication is also possible through accessory canals. The apical foramen is the last portion of the tooth to form. In developing teeth, the foramen is large and centrally located, and as the tooth matures the foramen becomes smaller in diameter.

Occasionally, within the pulp tissue there are calcified masses, these masses are called pulp stones, these stones are either calcified masses of dentine complete with tubules and processes (true pulp stone), or they are amorphous in structure (false pulp stone). Pulp stones could be free (unattached) to the outer pulpal wall or they can be attached to dentine at the dentinopulpal interface. These stones could create a problem only during endodontic therapy (Cohen et al., 2006, Nanci 2008).

2.3.3.1 Cells of the dental pulp

The majority of the pulp cells of newly erupted teeth are undifferentiated cells and fibroblasts. Occasionally, macrophages and white blood cells may be found. Mast cells are not often found in normal healthy pulp, but they are commonly found in inflamed pulp. Dendritic (and most likely immunocompetent cells) are also normally present in the pulp. Microscopically, dental pulp is composed of four zones; the odontoblastic layer, a cell-free zone or cell-poor zone, a cell-rich zone and a pulp core zone. The odontoblastic layer lines the outer pulpal wall and consists of the cell bodies of the odontoblasts. It also contains the cell bodies of afferent axons which are located between the cell bodies of the odontoblasts. In addition, capillaries, nerve fibres and dendritic cells may be found within this layer. The second layer is the cell-free layer and this contains fewer cells than the odontoblastic layer and the nerve and capillary plexus is located here. In the third layer the cell-rich zone there is an increase in density of cells and a more extensive vascular system contrasting with the second zone. In the fourth zone the pulpal core zone which is the inner most zone of the pulp, there are many cells and an extensive vascular supply (James et al., 2002).

2.3.3.2 Blood vessels and dental pulp hemodynamics

Arterioles and venules enter and leave the dental pulp via the apical foramen and also through lateral (accessory) canals. The pulp is abundantly vascularised, and all capillaries in the subodontoblastic layer are normally not functional at the same time; if necessary, the non-functional capillaries and arterioles may be filled quickly and an almost immediate local or general hyperaemia may be established in the odontoblast/subodontoblast layer. At the same time, any increase in tissue pressure cannot be rapidly equilibrated by expansion of the pulp although the pulp has some capacity of auto-regulation of blood flow. Lymph vessels are also present in the pulp; their main function is to remove excess filtered fluid and plasma proteins (James et al., 2002, Bath-Balogh and Fehrenbach 2005, Cohen et al., 2006, Nanci 2008, Ørstavik and Ford 2008).

2.3.3.3 Nerves in the dental pulp

Myelinated and unmyelinated nerves are abundantly present in the pulp. The majority of the nerves are sensory while sympathetic nerves have been reported to make up no more than 10% in fully developed teeth. Most of the nerves terminate in the coronal pulp and less than 10% of the nerve endings are found in the root pulp. An abundant plexus of nerves is found in the subodontoblastic layer and some nerves also extend into the peri-odontoblastic space of the predentine (James et al., 2002, Bath-Balogh and Fehrenbach 2005).

2.3.3.4 Dental pulp inflammatory reactions

When the pulp is traumatised, the loose connective tissue will act in response via an inflammatory reaction like any other connective tissue (Cohen 2006). However, and in contrast to inflammation elsewhere in connective tissue, this reaction takes place under special circumstances in a rigid chamber which in some measure makes the pulp vulnerable, as the pulp space cannot expand and gain in blood volume or interstitial fluid volume. In consequence, an increase in pulpal tissue pressure, which might compress the vessels, will lead to a counteracting of any beneficial effect from increased blood flow during pulpitis (Bath-Balogh and Fehrenbach 2005, Cohen et al., 2006, Nanci 2008).

As the preliminary reactions during any inflammation are vasodilatation and increase vascular permeability (which increases both the volume of blood and interstitial fluid) the pulp will respond with an increased tissue pressure. The degree and duration of increased tissue pressure in inflamed pulp will depend on the degree of severity and state of inflammation. In spite of increased blood flow and vascular permeability due to inflammation, the effective removal of plasma and lymph ensures that the tissue pressure does not rise to the level of vessel compression and resulting necrosis (Cohen et al., 2006). Thus, local coronal pulpits may persist without spreading to the root pulp.

Therefore, pulp may heal by removing permanently the injurious agents or by sealing off by reactions in dentine. However, in cases of severe and persistent irritants, the inflammation may spread in the apical direction and could cause total pulp necrosis (Cohen et al., 2006, Nanci 2008, Ørstavik and Ford 2008).

2.3.4 Dental trauma

In this part of this review, a critical evaluation of published literature will consider various aspects of dental trauma under the following main categories:

a. Introduction and methodology of dental trauma studies

b. Epidemiology of dental trauma (age, gender, geographic and incidence)

c. Aetiology of dental trauma

d. Diagnosis and assessment of dental trauma (including the classifications)

e. Pulpal response to dental trauma and pathogenesis of dental trauma

f. Pulpal prognosis and sequelae of trauma

2.3.4.1 Introduction and methodology of dental trauma studies

Many studies have been published where information was gathered on the outcomes of pulpal and initial subsequent root canal treatment. However, this literature is characterised by a great diversity in the reported outcomes. The principal reason for diversity in reported outcomes would appear to be differences in the variables of the studies such as:

1. Tooth position (Anterior/Posterior)
2. Number of roots
3. Case selection criteria
4. Proportion of teeth with apical periodontitis
5. Previous endodontic treatment
6. Treatment providers
7. Asepsis
8. Intra-canal procedures
8. Restoration type
9. Study design
10. Data collection
11. Recall rate
12. Interpretation of radiographs
13. Follow-up period
14. Sample size
15. Data analysis
16. Outcomes assessment criteria

This diversity can be confusing for the conscientious clinician looking for evidence of the benefits and outcomes of endodontic treatment as a basis for clinical decision-making (Friedman et al., 2003, Ørstavik and Ford 2008). Despite the vast information presented, answers to the main question related to the prognosis of pulpal and endodontic treatment among traumatised teeth remains obscured by the non-standardised material and methods of many studies. At the same time, a review of these mixed studies could be ineffective and potentially ambiguous. The answer to any question on the sequelae and prognosis of pulpal and endodontic treatment among traumatised teeth requires a study that focuses on cases selected according to well-defined criteria (Ørstavik and Ford 2008).

The outcomes of pulpal and non-surgical root canal treatment (NSRCT) have typically been studied using clinical signs and symptoms and/or radiographic findings. Another method of studying outcomes is through the use of epidemiological methods. However, most of these studies have dealt with NSRCT consequent to varieties of causes (such as dental decay but excluding dental trauma) (Lazarski et al., 2001, Imura et al., 2007).

Ordinarily, outcome studies can be designed using one of two major approaches: prospective or retrospective. Randomised controlled trials (RCTs) are considered as the gold standard by which all clinical research is judged (Hoskinson et al., 2002). However, the low failure rate and long follow-up times needed in endodontics makes this kind of study often underpowered and very expensive to conduct. Meta-analysis could be conducted if the studies were judged sufficiently similar in terms of types of patients, design and intervention. This type of study design is becoming frequently used to achieve conclusions about clinical decisions. Systematic reviews may also include meta-analyses and/or cumulative meta-analysis, as they permit appraisal of the additional contributions made by individual studies to the cumulatively pooled results of the previous studies (Kojima et al., 2004, Moles et al., 2005).

Alternatively, retrospective studies have the advantages of larger study populations, longer follow-up periods and are often protected from bias because data were often collected for reasons other than the study question. However, a major limitation in retrospective studies is the lack of ability to randomise and standardise the experiment, findings need careful interpretation and a cautious application to the general population. Furthermore, important data may not have been collected, accordingly limiting the scope of analysis.

2.3.4.2 Epidemiology of dental trauma

Dental trauma has been described in the literature in many countries. In some recently quoted studies the prevalence levels range from 1.8% in Norway to 34% in Saudi Arabia and 37.9% in Chile. This confirms that the prevalence of dental injuries is high (Andreasen 1970a, Andreasen and Ravn 1972, Hedegard and Stalhane 1973, Ravn 1974, Garcia et al., 1986, Todd and Dodd 1985, Forsberg 1993, Vanderas and Papagiannailis 1999, Marcenes et al., 1999, Tesini and Soporowski 2000, Al-Majed et al., 2001, Barnett 2002, Andreasen et al., 2007, Hasan et al., 2010, Faus-Damia et al., 2011). These findings have mostly been based on retrospective, cross-sectional clinical studies where signs of previous dental trauma have been noted with fewer prospective studies being completed where a population has been followed for a particular time period. Taken together, most of these studies show that trauma is the most common cause of loss of anterior teeth.

Trauma to the anterior teeth remains a common accident to children in the UK. This is the view of the UK National Child Dental Health Surveys that were carried out in 1993 and 2003 (Jackson et al., 2006), which found 17% of 15-year olds had received trauma to their incisors. At the same time, prospectively designed studies carried out in Denmark, have shown that half of all children are likely to experience at least one dental injury before leaving school (Andreasen and Ravn 1972, Marcenes et al., 1999). In Sweden, retrospective research showed that 35% of 16 year old children studied had on one or more occasions sustained dental injury (Borssen and Holm 1997).

Currently, dental trauma would appear to be one of the most common dental health problems, especially at a young age when growth and development takes place (Andreasen et al., 2007, Glendor 2008). In addition, dental trauma occurs frequently and is one of the most common reasons for which people seek treatment in all dental clinics and hospitals in a country (Eilert et al., 1997, Glendor 2008). Moreover, treatment of dental trauma can often be complicated and expensive (Glendor et al., 2001, Glendor 2008). In contrast to many other traumatic injuries, treatment of dental trauma usually takes place on an outpatient basis. Additionally, dental trauma is mostly irreversible and thus treatment will likely continue for the rest of the patient's life (Glendor et al., 2001, Andreasen et al., 2007, Glendor 2008). This may have an impact on children's quality of life especially as the majority of dental trauma involves the anterior teeth (Rock et al., 1974, Stalhane and Hedegard 1975, Todd and Dodd 1985, Jackson et al., 2006, Andreasen et al., 2007, Aldrigui et al., 2011).

Many studies have investigated the epidemiology of dental trauma and show that the peak accident time for dental trauma for the permanent dentition is found between 7 and 15 years (Magnusson and Holm 1969, Glendor 2008). At the same time, the anterior teeth are the most frequently injured teeth and the most commonly injured among them following trauma are maxillary central incisors and the least commonly injured are the maxillary and mandibular canines (Rock et al., 1974, Stalhane and Hedegard 1975, Andreasen et al., 1981a, Andreasen et al., 2007). In addition, dental trauma is considered to be the most common cause of loss of permanent anterior teeth in childhood (Todd and Dodd 1985, Marcenes et al., 1999, Andreasen et al., 2007). However, it is the potential for dental trauma to cause loss of vitality of the dental pulp, and the subsequent consequences of pulpal necrosis, which have the greatest bearing on the long-term prognosis of traumatised teeth (Andreasen and Pedersen 1985, Andreasen et al., 2003).

With regard to differences in gender distribution, it has been reported in some literature that the gender distribution was not significantly different and the potential for dental trauma was in actual fact dependant on the individual's activity and living environment (Glendor 2008). Other studies show that males experienced significantly more dental trauma to the permanent dentition than females (Forsberg and Tedestam 1990, Oulis and Berdouses 1996, Hamilton et al., 1997, Bastone et al., 2000).

2.3.4.3 Aetiology of dental trauma

Dental trauma may be inflicted in a number of ways; it can be the result of either direct or indirect trauma. Direct trauma occurs when the teeth themselves are struck, while indirect trauma is seen when the lower teeth are forcefully closed against the upper teeth. Most of direct trauma implies injuries to the anterior region, while indirect trauma implies injuries in premolar and molar regions. It would appear that many injuries result from falls and collisions which occur during playing and running or cycling, especially during the first years of childhood. This occurrence reaches the peak during school years where accidents in the school playground are common. Traumatic dental injuries related to fights tend to be more common in older individuals. In general, sports injuries usually occur in teenage years and are commonly associated with contact sports such as football, rugby, ice hockey and basketball. Injures related to road traffic accidents and assaults are most commonly associated with later teenage years and adulthood, and are often potentially a result of alcohol and/or drug use. In addition, child physical abuse or non-accidental injury could be one of the causes of dental trauma.

There are some factors which may predispose to traumatic dental injuries such as, increased over-jet, protrusion of the maxillary incisors and insufficient lip closure. There are some other factors that can influence the outcome or type of injuries such as energy of impact, resilience of impacting object, shape of impacting object and angle and direction of impacting object (Andreasen and Ravn 1972, Stalhane and Hedegard 1975, Todd and Dodd 1985, Forsberg et al., 1993a, Marcenes et al., 1999, Bastone et al., 2000, Tesini and Soporowski 2000, Al-Majed et al., 2001, Andreasen et al., 2003, Glendor 2008).

2.3.4.4 Diagnosis and assessment of dental trauma

Comparison and accumulation of data from different studies is extremely problematic, because of the different ways of description and classification of dental trauma used. Andreasen's classification (Andreasen 1981- Appendix 1) contains 19 groups which include injuries to the teeth, supporting structures, gingiva and oral mucosa. This classification is a modification of the World Health Organisation's (WHO) classification (WHO 1978- Appendix 1), which has been used by other authors. The Ellis classification (Ellis 1970- Appendix 1) is another system which has been used by various authors for recording dental trauma (Bastone et al., 2000). In addition while there are numerous classification systems currently available, a number of authors have also proposed descriptions and classifications of dental trauma and supporting structures, depending on the main aim of their studies and this could also enhance the difficulties when comparing studies.

2.3.4.5 Pulpal response to dental trauma and pathogenesis of dental trauma

The consequences of dental trauma can vary from complete recovery to the loss of the tooth. Trauma to the dento-alveolar complex may cause several types of injury; from fracture of the dental hard tissue to absolute displacement of the tooth from it is socket. It is unusual for a tooth to suffer both fracture and displacement (Rock and Grundy 1981). Occasionally, a tooth may be lost as an immediate result of trauma. However, the most common complication following dental trauma is pulpal necrosis (Andresen and Pedersen 1985).

After a tooth suffers an injury that leads to tooth displacement in any direction (luxation injury), there may be partial or total disruption of neurovascular supply of dental pulp which enters the root canal through the narrow apical foramen. Limited movement of the apical region may result in partial disruption but a reduced circulation can often still be maintained throughout the pulp, with complete reconstitution of neurovasculature after a few weeks (Kling et al., 1986, Andreasen 1989a, Andreasen et al., 1995, Barnett 2002). More severe displacement of the tooth can cause total rupture of the neurovascular supply but gradual revascularisation may take place. Dental trauma may also result in fracture of a crown, with the possibility of bacterial infection of dental pulp either through direct exposure or via the dentinal tubules (Lin and Langeland 1981). The signs of successful revascularisation are a narrowing of the pulp canal and a positive response to pulp sensibility testing (electric or cold pulp test) which usually takes place after two to three months. Unsuccessful pulp healing with an infected pulp is marked radiographically as a periapical radiolucency, which may be seen after two to four weeks (Andreasen et al., 2003).

Loss of tooth vitality is a common sequel to traumatic injury. If pulp necrosis is diagnosed immediately, there is a good chance of success for endodontic therapy and long-term retention of the involved tooth. On the other hand, if the pulp necrosis is diagnosed late, severe damage such as internal or external inflammatory root resorption, arrested root formation or periradicular inflammation will result. It is thus clear that, early management and regular follow-up of traumatised teeth may reduce the incidence of such damage (Andreasen 1985, Andreasen et al., 1989, Hulsmannet and Engelke 1991, AL-Nazhan et al., 1995).

Necrosis of the pulp, arrested root development, calcific metamorphosis, apical periodontitis and resorption (internal or external) may result from dental trauma (Andreasen 1985, Barnett 2002, Andersson 2007). Arrested root development may have serious long-term implications for immature teeth (Cvek 1992). Although Hertwig's epithelial root sheath, which is responsible for the root development, can be damaged by trauma, root formation can occasionally continue despite pulpal inflammation and even necrosis

(Andreasen and Hjörting-Hansen 1967, Heithersay 1970, Heithersay 1975, Feiglin 1985, Yang et al., 1990, Welbury 1999). The complete destruction of Hertwig's epithelial root sheath will result in failure of normal root development. Even in this situation, apical hard tissue can occasionally be formed by cementoblasts in the apical area and/or by fibroblasts from the dental follicle and periodontal ligament (Torneck 1982, Kahler et al., 2008).

2.3.4.6 Pulpal prognosis and sequelae of trauma

The most common complication following dental trauma is pulpal necrosis (Andresen 1985). Teeth of completed root formation demonstrated a greater risk of pulp necrosis than teeth of incomplete root formation. Pulpal necrosis may occur in several ways; the main neurovascular supply to the dental pulp enters the root canal through the narrow apical foramen and is therefore vulnerable to damage if the root apex is moved. Limited movement may result in damage to the thin walled venous system resulting in venous congestion and pulpal ischemia, while more severe displacement of the tooth may rupture the entire neurovascular supply, resulting in complete pulpal infarction. Dental trauma may also result in fracture of the crown, with possibility of bacterial infection of dental pulp, either through direct exposure or by way of dentinal tubules (Lin and Langeland 1981).

The most significant factors which play an important role in determining pulpal prognosis are type of injury, stage of root development and time elapsed before treatment (Andreasen 1985). In addition, other factors found to have a significant or nearly significant effect on the development of pulp necrosis are: age of patients; degree of dislocation; reduction and repositioning procedure; type of fixation; and the restoration in place (Skieller 1960, Arwill et al., 1967, Andreasen 1970, Rock and Grundy 1980, Jacobsen 1980, Dumsha and Hovland 1982, Andreasen 1985, Tronstad 1986, Andreasen and Thomsen 1986, Andreasen 1988, Barnett 2002). Additionally, arrested root development and apical periodontitis may result from trauma, especially to immature teeth (Andreasen et al., 2007). It has been reported that arrested root development may lead to serious long-term implications such as root fracture and tooth loss (Cvek 1992).

Moreover, it has been documented that root resorption was a frequent sequel to dental trauma either as a consequence of direct trauma or indirectly due to subsequent infection. Three types of resorption following trauma have been described: surface resorption; replacement root resorption; and inflammatory root resorption (Andreasen et al., 2007). The most common types of root resorption seen in root surfaces of traumatised teeth are replacement and inflammatory resorption. Surface and replacement resorption are trauma-induced, whereas inflammatory root resorption is induced by the combination of traumatic injury and infection of the necrotic root canal system (Trope 2002, Moule and Moule 2007).

2.3.5 Treatment and management of dental trauma and roles of pulpal and endodontic therapy in the treatment of traumatised teeth

The predominant concern of dentistry has traditionally been the treatment and prevention of dental caries. With the decrease in prevalence of dental caries, dental public health has become more aware and concerned with other oral health issues such as dental trauma (Harold et al., 2005, Andreasen et al., 2007, Glendor 2008). Dental trauma and consequent irreversible pathology can be extremely distressing for children as well as their parents. Prompt treatment is essential for the long-term health of a traumatised tooth. Obtaining dental care or not can make the difference between saving and losing a tooth.

It is generally accepted that the anterior maxillary teeth are the most frequently traumatised teeth during childhood. Occasionally, post-traumatic complications lead to tooth fracture or tooth loss. Dental trauma that results in displaced, fractured or lost teeth can have a significant negative functional, aesthetic, and psychological effect on children. For that reason, an appropriate treatment plan after a dental trauma is important for a good prognosis. The consequences of dental trauma can vary from complete recovery to the loss of the tooth. For this reason the selection of an appropriate treatment is essential and depending on the type of trauma, can vary from a simple procedure such as reattachment of a fractured enamel fragment in the case of simple enamel fracture, to a sophisticated procedure such as re-implantation and splinting an avulsed tooth followed by endodontic treatment.

The next sections of this review will consider various aspects of pulpal and endodontic therapy (dependant on the types of dental trauma sustained) as options for the management of permanent anterior traumatised teeth:

2.3.5.1 Infraction

In cases of infraction (incomplete fracture of the enamel without loss of tooth structure) the treatment objective is to maintain structural integrity and pulp viability by sealing the cracks using an enamel adhesive system. The general prognosis of this kind of trauma is usually good and rarely results in complications (Andreasen et al., 2007, Andersson et al., 2010).

2.3.5.2 Uncomplicated Crown Fracture

When the trauma involves enamel or enamel and dentine, and the pulp is not exposed (uncomplicated crown fracture), the treatment objective is to maintain pulp vitality and restore normal aesthetics and function. For small fractures, any rough margins and edges can be smoothed. For larger fractures, the lost tooth structure can be restored either by bonding the tooth fragment if it is available or with an appropriate tooth coloured dental restorative material (Andersson et al., 2010). Emergency treatment prior to definitive restoration is important and comprises covering the exposed dentine with a material such as glass ionomer cement (Friedmen et al., 1995, Andreasen and Andreasen 2000, Flores et al. 2001, Flores et al., 2007,).The prognosis of uncomplicated crown fractures depends primarily upon the associated injury to the periodontal ligament and secondarily upon the extent of dentine exposed (Andreasen and Andreasen 2000).

2.3.5.3 Complicated Crown Fracture

When the clinical and radiographic findings confirm loss of tooth structure with pulp exposure (complicated crown fracture), the treatment objectives are to maintain pulp vitality and restore normal aesthetics and function (AAPD 2007). Pulpal treatment alternatives are direct pulp capping, partial pulpotomy, and pulpectomy (Andreasen and Andreasen 2000, Flores et al., 2001). In young patients with immature (developing) teeth, it is advantageous to try and preserve pulp vitality by either pulp capping or partial pulpotomy. These options are also the treatment of choice in young patients with completely formed roots. Conventional calcium hydroxide ($Ca(OH)_2$) and Mineral Trioxide Aggregate (MTA) are suitable materials for such procedures. In older patients, conventional root canal treatment can be the treatment of choice, although pulp capping or partial pulpotomy may also be selected. However, if a long time elapses between the accident and treatment, and the pulp becomes necrotic then root canal treatment is indicated to preserve the tooth. The prognosis for complicated crown fractures appears also to be dependant on any associated periodontal ligament injury (Andreasen and Andreasen 2000). At the same time, the prognosis depends on the time elapsed since the pulp was exposed, the extent of dentine exposed, and stage of root development at the time of injury (Andreasen and Andreasen 2000).

2.3.5.4 Crown Root Fracture

When the enamel, dentine, and cementum of the tooth are fractured, with or without pulp exposure (crown root fracture), the objective of dental treatment is to maintain pulp vitality and restore normal aesthetics and function (Tapias et al., 2003). An emergency treatment step, namely stabilising the coronal fragment using bonding agents may be advantageous, but the definitive treatment alternatives are still to remove the coronal fragment followed by a supragingival restoration with or without gingivectomy, osteotomy, or surgical or orthodontic extrusion to allow satisfactory restoration. Pulp capping, pulpotomy, and root canal treatment becomes one of the treatment alternatives if the pulp is exposed, (Andreasen 2000, Flores et al., 2001, Olsburgh et al., 2002). The general prognosis of this type of trauma can be complex and most of the teeth that suffer these injuries can be saved (Andreasen 2000). At the same time, if the fracture extends significantly below the gingival margin then the complexity of restoration increases.

2.3.5.5 Root Fracture

Where the clinical findings reveal a mobile coronal fragment attached to the gingiva, that may be displaced, then the fracture must involve dentine, cementum and pulp. The treatment objectives here are to optimise healing of the periodontal ligament and neurovascular supply while maintaining aesthetic and functional integrity. This may be achieved by repositioning the coronal tooth fragment as soon as possible and stabilising the coronal fragment in its anatomically correct position with a flexible splint for 4 weeks. If the root fracture is near the cervical area of the tooth, stabilisation is beneficial for a longer period of time (up to four months) (Andreasen and Andreasen 2000, Andreasen et al., 2007, Flores et al., 2007, Andersson et al., 2010). The location of the root fracture has not been shown to affect pulp survival after injury (Andreasen 2000; Andreasen et al., 2004).

In general, preservation of teeth with root fractures occurring in the tooth cervical third should be attempted (Andreasen 2000, Andreasen et al. 2004). It is advisable to monitor healing for at least 1 year in root fractured teeth to determine pulpal status. If pulp necrosis develops, it is usually attributed to displacement of the coronal fragment and maturity of the root (Andreasen 2000). In such cases root canal treatment of the coronal tooth fragment to the fracture line is indicated to preserve the tooth.

2.3.5.6 Concussion

If the trauma was limited to the tooth-supporting structures without abnormal loosening or displacement of the tooth (concussion), the treatment aim is to optimize healing of the periodontal ligament and maintain pulp vitality (Andreasen 2000, Flores et al., 2001, Andreasen et al., 2007, Flores et al., 2007). At the same time, pulpal therapy is not usually indicated but clinicians should monitor the pulpal condition for at least one year (Flores et al. 2007). The general prognosis of this kind of trauma is usually good. However careful monitoring and follow-up is recommended for mature permanent teeth with closed apices which may undergo pulpal necrosis due to associated injuries to the blood vessels at the apex (Andreasen and Andreasen 2000, Moule and Moule 2007).

2.3.5.7 Subluxation

For subluxation cases where the injury is limited to tooth supporting structures with abnormal loosening of the tooth but without tooth displacement, the treatment objectives are to optimise healing of the periodontal ligament and neurovascular supply (Andreasen et al., 2007, Flores et al., 2007, Moule and Moule 2007, Andersson et al., 2010). This can be achieved through stabilisation of the tooth with a flexible splint for up to two weeks, perhaps also relieving any occlusal interference (Flores et al., 2007). The prognosis is usually favourable (Moule and Moule 2007, AAPD 2007). However, endodontic treatment may be necessary because of the potential for pulpal necrosis to develop due to associated injuries to the blood vessels at the apex (Andreasen 2000, Moule et al., 2007).

2.3.5.8 Lateral luxation

Tooth displacement in any direction other than axially can lead to tearing of the periodontal ligament and fracture of the supporting alveolar bone (Nikoui et al., 2003). As a result, repositioning of the tooth as soon as possible and stabilisation of the tooth in its anatomically correct position using a flexible splint for 2-4 weeks is recommended in order to facilitate optimal healing of the periodontal ligament and neurovascular supply, while maintaining aesthetic and functional integrity (Nikoui et al., 2003, Andreasen et al., 2007, Flores et al., 2007, Moule and Moule 2007). Monitoring of the pulpal condition is essential as pulp necrosis and pulp canal obliteration are common healing complications while progressive root resorption is less likely to occur (Nikoui et al., 2003). If the pulp becomes necrotic, root canal treatment is indicated to prevent root resorption (Andreasen et al., 2007, Flores et al., 2007).

2.3.5.9 Intrusive luxation

In apical displacement cases the tooth is displaced into the socket and this will compress the periodontal ligament and commonly cause a crushing fracture of the alveolar socket (Humphrey et al., 2003). There is considerable risk of pulp necrosis, pulp canal obliteration, and progressive root resorption especially in cases of mature teeth with closed apices (Humphrey et al., 2003). Repositioning of the tooth orthodontically or surgical extrusion followed by initiation of endodontic treatment within the first three weeks after the traumatic injury is recommended to retain the tooth (Crona et al., 1991, Andreasen 2000, Humphrey et al., 2003, Andreasen et al., 2007, Flores et al. 2007).

2.3.5.10 Extrusion luxation

The periodontal ligament is usually torn if the tooth is partially displaced axially from the socket (partially avulsed) (Lee et al., 2003). To promote the healing of the periodontal ligament and neurovascular supply, repositioning of the tooth as soon as possible and then stabilisation of the tooth for up to two weeks with a flexible splint in its anatomically correct position is recommended (Crona et al., 1991, Andreasen 2000, Lee et al., 2003, Andreasen et al., 2007, Flores et al., 2007). The risk of pulp necrosis is considerable especially in cases of mature closed apices (Lee et al., 2003). For this reason, these teeth must be followed carefully and should the pulp become necrotic and infected then endodontic treatment is indicated (Andreasen 2000, Flores et al. 2007).

2.3.5.11 Avulsion

When a traumatic injury totally displaces a tooth from its socket the periodontal ligament is detached and fracture of the alveolus may occur (Moule and Moule 2007). In this kind of injury and, according to the guidelines for the management of traumatic dental injuries of avulsion of permanent teeth, it is recommended to replant the tooth as soon as possible and then to stabilise the replanted tooth in its anatomically correct position for about two weeks using a flexible splint in order to optimize healing of the periodontal ligament and neurovascular supply while maintaining aesthetic and functional integrity (Flores et al. 2007, AAPD 2007).

The prognosis for the avulsed permanent teeth is primarily dependent upon the stage of root development and the extra-alveolar dry time (EADT) (Andreasen et al., 2007, Flores et al., 2007). The best prognosis is considered to be if the tooth has been replanted immediately (Andreasen et al., 2007, Andersson et al., 2010). Transportation media for avulsed teeth is important and can play a significant role in the long-term prognosis of avulsed teeth. In avulsed teeth, there is considerable risk of pulp necrosis, root resorption or ankylosis. Previously, it was recommended that in mature teeth the endodontic therapy should be commenced seven to ten days following re-plantation (Flores et al. 2001, Finucane and Kinirons 2003). More recently however it was recommended that pulp extirpation should be carried out as soon as possible to prevent the initiation of inflammatory root resorption (Flores et al., 2007). In immature teeth, where the extra alveolar time is short and the apex is still open, it is recognised that revascularisation of the pulp may occur. Therefore endodontic therapy can be delayed. At the same time, regular follow-up is advisable and apexification procedures should be initiated at the first sign of resorption, discolouration, and the presence of a draining sinus or periapical bone loss (Flores et al. 2001).

Having mentioned this, the management of immature non-vital teeth following trauma or pulpal infection is a challenge. Debridement of the root canal system followed by dressing with materials such as $NSCa(OH)_2$ in order to induce an apical barrier formation a ‘apexification’, or using a another material (i.e. MTA) to create an immediate barrier, can result in brittleness with teeth susceptible to root fracture in addition to not producing any increase in root length (Shabahang et al. 2000, Andreasen et al. 2002a, Rafter 2005, Twati et al. 2009). The ideal treatment to obtain further root development and thickening of dentinal walls in an immature tooth would be to stimulate the regeneration of a functional pulp-dentine complex (Iwaya et al. 2001, Banchs and Trope 2004, Chueh & Huang 2006). Consequently, a new biologically-based treatment approach was recently introduced to manage non-vital traumatised teeth with incomplete root development (Regenerative Endodontic Technique). This can be defined as a biologically based procedure designed to replace damaged structures, including dentine and root structures, as well as cells of the pulp-dentine complex with objectives to regenerate pulp-like tissue, ideally, the pulp-dentine complex (Murray et al. 2007, Duggal & Tong 2010, Thomson & Kahler 2010). These regenerative endodontic techniques will involve some combination of disinfection and debridement of infected root canal systems together with apical enlargement to permit revascularization and use of adult stem cells, scaffolds, and growth factors.

2.3.6 Summary

Despite the existing diversity in the current dental trauma literature, the review confirms that dental trauma in children occurs frequently. The exact prevalence of dental trauma especially in anterior teeth is common and varies from 1.8% to 37%. Overall, the peak age of prevalence of dental trauma among permanent anterior teeth was recorded among the 7–15 years age group and this literature review shows that the gender distribution was not significantly different and that the potential for dental trauma was in actual fact dependent on the individual's activity and living environment. However, the majority of the studies reported that males experienced more dental trauma to the permanent dentition than females.

Additionally, it was obvious that most of the dental injuries result from falls and collisions while playing and running or cycling especially during the first years of childhood. This occurrence reaches a peak during school years where accidents in the school playground are common. In addition, the review shows that there are some factors which may predispose to traumatic dental injuries such as, increased overjet, protrusion of upper incisors and insufficient lip closure.

The review illustrates that the consequences of dental trauma can vary from complete recovery of tooth vitality and function to the loss of the tooth, depending on the type of trauma. Furthermore, the selection of an appropriate treatment depends upon the type of trauma, and varies from simple procedures such as reattachment of the fractured enamel / enamel-dentine fragment in cases of uncomplicated fractures to more sophisticated and complex procedures such as replantation and splinting of avulsed teeth followed by endodontic treatment.

The outcomes of pulpal and root canal treatment (RCT) have typically been studied using clinical signs and symptoms and/or radiographic findings. However, many of these studies have dealt with NSRCT consequent to a variety of causes such as dental decay or for prosthetic purposes but excluding dental trauma. Moreover, the review shows that the comparison and accumulation of data from different studies is extremely problematic, because of the different ways of descriptions and classifications of dental trauma reported, as well as a lack of uniformity in the definitions of diagnostic criteria.

Regardless of the vast information presented, the review makes the point that the answers to the main questions relating to the prognosis of pulpal and endodontic treatment among traumatised permanent anterior teeth remain obscured by the non-standardised material and methods of many studies. Furthermore review of these mixed studies could be ineffective and potentially ambiguous. To answer the question about the sequelae and prognosis of pulpal and endodontic treatment among traumatised teeth really requires a new study that would focus on cases selected according to well-defined criteria.

2.4 Dental Avulsion

2.4.1 Introduction

Dental trauma has a psychological and social impact on patients and their parents, with consequences that may impair the child's social functioning and emotional stability. A recent Canadian study showed that trauma to the anterior teeth and especially maxillary incisors had a greater social impact than on functional or psychological development, especially amongst 12 to 14 year-old children (Fakhruddin et al., 2008). Avulsion injuries are distressing injuries and when injuries occur they can affect the daily life of both patients and their parents compared to families without any history of trauma (Cortes et al., 2002). Caglayan and Aldrigui revealed that dental trauma had the most negative effect on the quality of life (Caglayan et al., 2009, Aldrigui et al., 2011). Similarly Gianetti stated that dental avulsion impaired oral health quality of life, especially in patients under 18 years old (Giannetti et al., 2007). This effect on oral health quality of life could be amplified by increasing the number of lost teeth (Steele et al., 2004).

Tooth avulsion has been a problem for many years and is one of the most serious dental injuries. It requires urgent and appropriate management to prevent any further complications (Andreasen et al., 2007, Andersson et al., 2010). Traumatic dental avulsion can be defined as the traumatic detachment of a tooth from the dental arch. Andreasen has defined dental avulsion as a complete displacement of the tooth out from the socket (Andreasen et al., 2007). Some others have defined dental avulsion as a total luxation where the tooth is displaced totally out of the socket in the coronal direction (Roberts and Longhurst 2008).

Traumatic avulsion injuries are emergencies that require immediate treatment, aiming to reduce any suffering in addition to minimizing the chances that any complication might occur. Many studies have shown that loss of tooth vitality is frequent sequelae to traumatic avulsion injuries. Forthermore if pulp necrosis is diagnosed late then severe damage such as root resorption or arrested root formation will occur. On the other hand, endodontic treatment can provide a good chance for long term retention of the avulsed tooth. Therefore, replantation of permanent avulsed teeth should nearly always be attempted even though it might provide only a temporary solution given the frequent occurrence of root resorption. A resorbing tooth will still act as a natural space maintainer preserving the height and the width of the alveolus facilitating later treatment (i.e. implant placement) (Welbury and Gregg 2006, Andersson et al., 2010). Additionaly the positive effects of the treatment (replantation) on the psychological and emotional wellbeing of the patient cannot be underestimated.

It has been acknowledged for a long time that a replanted tooth following avulsion may function for many years and the healing following replantation has been extensively studied. Andreasen found that, under ideal conditions, complete healing of the pulp and the periodontal ligament can occur after replantation (Andreasen et al., 2007). However, such conditions rarely occur in ‘real life’. Consequently replantation of an avulsed tooth is often considered a temporary measure, providing a patient with a natural tooth until it is eventually replaced by a prosthesis. Despite the vast amount of information reported in the literature concerning dental avulsion, the association between the factors that could affect treatment outcomes remains obscure and still not clear enough to be able to predict the outcomes of the treatment. In addition, almost all the studies on dental injuries are not evidence based and this compounds the difficulty of analysing the long term prognosis of healing and its relationship to treatment. Randomized clinical studies are the ideal type of studies, but for ethical reasons, these will be remain difficult to achieve (Andreasen et al., 2010). A recent Cochrane review on what is the best treatment for avulsed teeth (Day and Duggal 2010) identified only three randomized controlled trials that were eligible for inclusion. Two of the studies were at high risk, with the third categorized as moderate risk of bias.

In light of this, this part of literature review aims to provide a better understanding of dental avulsion by reviewing the relevant literature on this topic, and thereby identifying a logical approach to this clinical issue.

2.4.2 Search strategy

The search included search of:

1. Electronic journals and database search, including Ovid, PUBMED, MEDLINE and others including the web of Knowldge. Using different searching terms and words such as Dental Avulsion, Tooth luxation, Tooth replantation, Traumatic avulsion, Storage medium, Extra alveolar time, Extra alveolar dry time, Root resorption, Inflammatory root resorption, Replacement root resorption, Ankylosis, Splinting, Treatment outcomes, Treatment sequel, Prognosis, Periodontal ligament, Incidence, Causes, Effects, Assessment of treatment

outcomes and others. These terms and words were assembled or arranged and put together to form a search string with using some Boolean operators such as AND, NOT, OR.

2. Hand search of textbooks, journals or articles on shelves of Glasgow dental hospital and school library. In addition to screening and follow-up of different references quoted in different individual papers.

3. Access to various websites.

The relevance of any study contained in this review should be considered by dental avulsion treatment outcomes of traumatised permanent teeth and/or approaches to improve the treatment outcomes. The range of search was not limited to publication date or any source of information. At the same time, it depended on the availability of the database source.

This part of this review starts with a discussion of the incidence and causes of dental avulsion. It then addresses the healing and pathology of the involved tissues following tooth avulsion and its treatment and management before considering outcomes and complications. Finally the effects of external factors on the prognosis of avulsed teeth are reviewed.

2.4.3 Epidemiology of traumatic dental avulsion

Dental avulsion would appear to be one of the most common dental health problems, especially during the early years of growth and development (Andreasen et al., 2007, Glendor 2008). According to the literature, the incidence of the dental trauma might soon eventually exceed the incidence of dental caries in some communities (Andreasen et al., 2007).

Cumulatively the prevalence of traumatic dental avulsion may comprise as much as 16% of all dental injuries to permanent anterior teeth (Andreasen 1981c, Granville-Garcia et al., 2009). The scientific literature reveals a varying incidence of dental avulsion (Andreasen 1970, York et al., 1978, Martin et al., 1990, Wright et al., 2007, Bruns and Perinpanayagam 2008). In a survey of about 1,298 dental trauma cases attending a general hospital the incidence of dental avulsion comprised about 16% of cases (Andreasen 1970). At the same time, Martin et al., found that incidence of dental avulsion cases among all dental trauma cases attending a dental hospital was about 13% (Martin et al., 1990). In contrast, York with a smaller survey involving only 72 dental trauma cases found only 3% of them were avulsion (York et al., 1978). However, this may be explained by the fact that only the most severe cases of dental trauma present at dental hospitals. In the recent literature, the level of avulsion amongst traumatised permanent anterior teeth is still high (20-23%) (Wright et al., 2007, Bruns and Perinpanayagam 2008).

In a comparison study about 12,000 children aged 12 to18 years old from two different socio-economic groups were recruited; the overall avulsion rate was 2.5%. However, in the group of lower socio-economic status, the avulsion rate was almost two-fold the figure of the higher socio-economic group (Burton et al., 1985). Another study considered the distribution of traumatically avulsed teeth and found that maxillary teeth were more likely to be avulsed compared to mandibular teeth by a ratio of 10:1 (Andreasen 1970). This was corroborated by Jarvinen in his retrospective study which included about 1,614 children where the most frequently injured teeth were the upper central incisors (81.7%) (Jarvinen 1979).

According to the literature, the majority of avulsion injuries are sustained between ages of 8 and 12 years as the roots of the teeth are usually incompletely formed and the supporting resilient alveolar bone provides only minimal resistance to extrusive forces and is easily deformed (Andreasen, 1981c, Marcenes et al., 1999). Similarly, Glendor reported that 83% of all individuals with tooth injuries were younger than 20 years (Glendor et al., 1996). Accordingly, childhood and adolescence is the most vulnerable period for traumatic avulsion injuries. Concerning the differences in gender distribution, it has been observed that some studies show that the gender distribution was not significantly different and the potential for dental trauma was in actual fact dependant on the individual’s activity and living environment (Glendor 2008). Other studies show that males experienced significantly more dental trauma to the permanent dentition than females (Forsberg and Tedestam 1990, Hamilton et al., 1997, Bastone et al., 2000).

Traumatic dental avulsion may be caused in a number of ways. It can be the result of either direct or indirect trauma, where any excessive force applied to the tooth will either lead to a fracture of the tooth or the force will be directed to the supporting structures causing displacement (Andreasen et al., 2007). It would appear that many avulsion injuries are caused by falls and collisions which occur during playing such as running or cycling, especially during the first years of childhood. This occurrence reaches a peak during school years when accidents in the school playground are common. Traumatic avulsion injuries related to fights tend to be more common in older individuals. In general, sports injuries usually occur in teenage years and are commonly associated with contact sports such as football, rugby, ice hockey and basketball. Injures related to road traffic accidents and assaults are most commonly associated with late teenage years and adulthood. Moreover, there are other factors which may predispose to traumatic avulsion injuries such as, increased overjet and protrusion of the maxillary incisors, in addition to the energy of impact, resilience of impacting object, shape of impacting object and angle and direction of impacting object (Forsberg and Tedestam 1993, Marcenes et al., 1999, Bastone et al., 2000, Tesini and Soporowski 2000, Al-Majed et al., 2001, Glendor 2008).

2.4.4 Healing and pathology of involved tissues following tooth avulsion

When a tooth is avulsed or totally luxated out of it is socket, the supporting mechanism of the tooth (periodontium) which is made up of periodontal ligament, cementum, alveolar bone and gingiva will damaged. The chances of bacterial infection are heightened during the extra alveolar time and this will alter the tissue reactions and responses to the injury. These reactions will take place especially in the dental pulp and periodontal ligament (Andreasen et al., 2007).

Because of the interruption of the neurovascular supply to the dental pulp during exarticulation, necrosis is virtually certain. Extensive pulpal changes particularly in the coronal part of the tooth could be observed as early as three days after replantation, and severe damage to the dental pulp is more likely to occur in teeth with mature roots and completed apices (Andreasen et al., 2007). A clinical study looking at the relationship between pulp necrosis and root development in luxated teeth, showed that 77% of teeth with complete root formation demonstrated pulp necrosis compared with 8% of teeth with immature roots (Andreasen and Pedersen 1985). During the extra alveolar period, bacteria may attack the dental pulp via the apical or accessory foramina or may gain access through the root surfaces via the dentinal tubules causing proteolytic digestion of the pulp (Bergenholtz 1974). On the other hand, signs of healing and maintenance of vitality is possible and this might be seen within two weeks of the injury, especially in teeth with open apices where the pulpal repair seems to be more rapid because of the great chance of revascularisation of the pulp tissue (Kling et al., 1986, Andreasen et al., 2007). Giving a tooth a chance to maintain vitality and revascularisation, especially for teeth with an immature root is important as this will allow to the root to complete its development in terms of both its length and the thickness of its dentinal walls.

As a consequence of tooth avulsion, the periodontal ligament is lacerated between its insertions at the bone and the cementum interfaces. The sequence of healing or necrosis of the periodontal ligament will depend on many factors. The most important is maintenance of cellular vitality of the innermost cell layers along the root surface (Lindskog et al., 1985, Andreasen 1981c). Primary repair and proliferation of the connective tissue cells might occur after three to four days of replantion (Andreasen et al., 2007). After one week the epithelium is reattached at the cemento-enamel junction (Andreasen 1980), which may help to reduce the risk of gingival infection and/or reduce the chance of bacterial invasion of periodontal ligament via the gingival pocket. This phase is followed by healing of the split line of periodontal ligament fibres which may occur after two weeks (Andreasen et al., 2007).

Andreasen in his book (Andreasen et al., 2007) suggests four different healing sequelae of periodontal ligament after avulsion and replantation:

- Healing with a normal periodontal ligament
- Healing with surface root resorption (repair-related root resorption)
- Healing with ankylosis (replacement resorption)
- Healing with inflammatory resorption (infection-related resorption)

Healing with a normal periodontal ligament will be discussed here. The other sequelae will be considered as part of treatment complications in this review. Normal healing could occur in a tooth that is replanted immediately under ideal conditions (the innermost cell layer of periodontal ligament is vital along the root surface) and is characterised histologically by complete regeneration of collagen fibres of the periodontal ligament (Andreasen and Hjörting-Hansen 1966, Heithersay et al., 1975, Andreasen et al., 2007). Clinically normal healing is characterised by normal tooth mobility and normal percussion. On x-ray examination, it is characterised by normal lamina dura (periodontal space) without any signs of root resorption. Practically the opportunity for this type of healing in traumatic dental avulsion is very low, as trauma will at least result in a minimal injury to the innermost cell layer of periodontal ligament leading to different sequelae of healing (i.e. healing with surface root resorption).

2.4.5 Treatment of dental avulsion

Avulsion injuries are emergencies that require immediate treatment aiming to reduce any suffering and to minimize complications. The treatment prognosis depends on the measures taken at the place of the accident or during the time immediately after the avulsion (Andreasen et al., 2007). Replantation is the treatment of choice and immediate replantation of the avulsed teeth has been recommended for many years, but cannot always be carried out immediately. Therefore, the treatment procedure starts when the patient, or an available adult or maybe the emergency department of a general hospital, contacts the dentist for advice about replantation. If the tooth is available it could be replaced into the socket immediately or if replantation cannot occur then the tooth should be placed into an appropriate storage medium. This initial advice is very important as it will help to make either the total extra alveolar time or the extra alveolar dry time shorter which will improve the prognosis significantly (Johnson et al., 1985, Barrett and Kenny 1997, Trope 1995). If the tooth was contaminated or dirty Weinstein and Andreasen (Weinstein et al., 1981, Andreasen et al., 2007) advised that the tooth should be cleaned by simply rinsing it under cold running water for about 10 seconds before replacing the tooth into its socket immediately thereby hoping to decrease the extent of root resorption. However some older literature did not recommend cleaning the tooth under water but alternatively advised immediately attending a dental clinic (Levenstein 1982).

Once the patient arrives at the dental clinic prompt action is required for accurate diagnosis which can be achieved through comprehensive clinical examination supported by a good history with appropriate investigations. Accurate records and careful documentation of the traumatic incident covering the period between the accident and attendance as well as the conditions under which the tooth has been stored, are essential for correct diagnosis. At the same time, collection of these relevant details might help in determination of tooth prognosis. Overall, Andreasen suggests that, at the time of initial treatment and before the replantation, there are some factors that should be considered which might affect the final outcomes of the treatment (Andreasen et al., 2007):

- Advanced periodontal disease
- Socket integrity
- Extra alveolar time period
- Stage of root formation

In recent years two articles attributed to the International Association of Dental Traumatology (IADT), have established and developed guidelines for the treatment of traumatic dental avulsion thus aiming to deliver the best care possible in an efficient manner (Flores et al., 2001, Flores et al., 2007).

Both articles emphasise the importance of replantation of avulsed teeth and highlight the issue that the dentist should be always ready and prepared to give appropriate advice about the initial management of avulsed teeth.

Equally, the two guidelines used the same classifications to summarise the different diagnostic situations of avulsed teeth:

1. Tooth with a closed apex
    a. The tooth has already been replanted
    b. The tooth has been kept in special storage media, with extra-oral dry time less than 60 min
    c. Extra-oral dry time longer than 60 min
2. Tooth with open apex
    a. The tooth has already been replanted
    b. The tooth has been kept in special storage media, with extra-oral dry time less than 60 min
    c. Extra-oral dry time longer than 60 min

Both guidelines are the same apart from the inclusion of some amendments in the 2007 guidelines:

- Splinting time which used to be one week has been increased to two weeks for all the diagnostic situations, except for those teeth with an extra-oral dry time of longer than 60 min which should be splinted for four weeks

- Treatment of avulsed teeth before replantation with different transport solutions aims to defeat and inhibit the expected root resorption. For teeth with a closed apex the time of immersing the tooth in a 2% sodium fluoride solution becomes 20 min instead of 5 min. At the same time, for those teeth with an open apex that were kept in a special storage media with an extra-oral dry time of less than 60 min, it is now recommended that the root surface be covered with minocycline hydrochloride before replanting the tooth instead of using doxycycline (1 mg/20 ml saline). This step could help to make a 50% reduction in the progression of root resorption of replanted teeth (Coccia 1980)

- The longevity of use of intracanal non-setting calcium hydroxide. In the 2007 guideline calcium hydroxide is recommended for intra-canal medication for up to one month followed by root canal filling with an acceptable material, instead of changing the calcium hydroxide dressing every three months till the lamina dura can be traced around the entire root surface. An exception is made for a tooth that has been dry for more than 60 min before replantation. In such cases the root canal treatment may be done prior to replantation

- For avulsed teeth with open apex and prolonged extra-oral dry time (longer than 60 min) replantation is now recommended even when delayed replantation suggests the tooth has a poor long term prognosis and the periodontal ligament will be necrotic. The purpose in doing delayed replantation of immature teeth is to maintain alveolar ridge height and contour. The eventual outcome is expected to be ankylosis and root resorption. It is important to recognize that if delayed replantation is done, then future treatment planning must take into account the occurrence of tooth ankylosis and the effect of ankylosis on the alveolar ridge development

2.4.6 Follow-up and treatment complications of dental avulsion

Many studies have shown that a loss of tooth vitality is a frequent sequel to traumatic avulsion injuries. If pulp necrosis is diagnosed late then severe damage such as root resorption or arrested root formation will occur. For this reason pulpal sensibility tests and radiographic examinations should be performed in the follow up period in order to disclose any pulp necrosis or root resorption, as these are the two main sequelae of avulsion injuries.

However, pulp sensibility tests are unreliable immediately after replantation. Revascularization might occur especially among immature teeth if the extra alveolar time was short, but it is very rare (Andreasen et al., 2007).

The two main consequences of pulpal necrosis are: termination of root development; and bacterial contamination of the pulpal space. The latter will become the driving force behind destruction of the root and the bone surrounding it unless it is prevented or addressed in a well-timed manner (Berman et al., 2007). Periodontal ligament damage (the main leading cause of root resorption) might occur as a result of periodontal ligament injury: drying; tearing of periodontal ligament and cementum from the root surface; and compression.

It has been documented that root resorption is a frequent sequel to dental trauma as a direct consequence of trauma or indirectly in the course of subsequent infection. Under typical circumstances, permanent teeth do not resorb. This fact appears to be due to anti-resorptive properties of precementum on the external surface of the root and of the predentine on the internal surface of the root (Trope 1998). Root resorption occurs because of stimulation of osteoclasts by the release of chemical mediators and results in a loss of hard dental structure (cementum and dentine) from the root surface. Three types of resorption following trauma have been described: surface resorption; replacement resorption; and inflammatory resorption (Andreasen et al., 2007, Berman et al., 2007, Moule and Moule, 2007).

Surface and replacement resorption are trauma induced, whereas inflammatory root resorption is induced by the combination of traumatic injury and infection of the necrotic root canal system. Surface resorption has been described as small resorbtive cavities of the root surface, usually limited to cementum. It is a self limiting resorption, usually repaired by newly formed cementum after injury (Berman et al., 2007). In traumatised teeth this type of resorption occurs more commonly in the apical portion of the root and may be seen as a shallow rounding of the tooth shape. It has been suggested that surface resorption does not affect the prognosis (Scott and Zelikow 1980). However, if the resorption cavities are deep and reach to dentine, and there is associated periodontal inflammatory reaction, then this could lead to a much more serious type of root resorption (inflammatory resorption) which requires immediate treatment intervention (Berman et al., 2007).

Inflammatory root resorption occurs entirely as a result of a necrotic and infected pulp. It can be recognized radiographically by the development of radiolucency in the bone adjacent to the resorptive defect which is characterized by bowl-shaped areas of loss of root structure. The process of inflammatory resorption can be very rapid and aggressive and may lead to the early loss of the tooth as early as three months after replantation (Andreasen et al., 2007). Progression of inflammatory root resorption after tooth replantation seems to occur in stages starting by initiation of the resorptive process when the trauma affects the cementum and the periodontal ligament. This subsequently leads to exposure of the dentinal tubules which will allow direct communication with the necrotic pulp tissue which in turn may initiate an inflammatory reaction in the periodontal ligament which subsequently stimulate the osteo-odontoclastic cells on the root surface (Andreasen 1985). This type of resorption is more aggressive in younger aged children because at this age the dentinal tubules are larger, and the distance from pulp canal to the root surface is small. At the same time, the activity of osteo-odontoclastic cells is amplified if the inflammation occurs as a consequence of the pulp necrosis (Berman et al., 2007). Removal of the infected pulp tissue, dressing with an anti-osteoclastic medicament (such as NS-$Ca(HO)_2$ or Ledermix paste) and subsequent filling of the root canal with gutta-percha will usually assist to stop the progress of the resorptive process (Andreasen et al., 2007, Berman et al., 2007). Two very recent multicentre randomized controlled trials (Day et al., 2011 and Day et al., 2012) compared the effects of the two commonly used root canal medicaments (NS-$Ca(HO)_2$ and Ledermix paste) on the tooth discoloration and on periodontal healing of avulsed teeth after replantation. They showed that there was no significant difference in periodontal healing between the two medicaments.

Replacement root resorption (ankylosis) usually occurs when there has been massive damage to the periodontal ligament and to the cementum following the avulsion injury, especially if the extra alveolar time was more than 60 min

(Berman et al., 2007). Andreasen has defined the ankylosis as fusion of cementum or dentine with alveolar bone which might be demonstrated as early as two weeks after replantation (Andreasen et al., 2007). The aetiology of this kind of root resorption appears to be related to the absence of vital periodontal ligament cells that normally cover the root surface. When the root surface becomes exposed to the alveolar bone the osteoclasts are stimulated by the organic matrix proteins and cytokines released from the surrounding bone and dentine. In contrast odontoblasts do not respond to the cytokines. Thus the root surface starts to be gradually replaced (replacement resorption) by bone (Lindskog et al., 1985, George and Evans 2009). Replacement resorption can be progressive or transient but if it is a progressive type then the prognosis is very poor. In most instances the entire root becomes involved over time. In these cases, the clinician may elect to allow the process to continue to its expected end result (total destruction of the root). This process usually takes about five years but may take much longer especially in older patients. Conversely if it is a transient type then it may disappear with time (Andreasen 1981d).

Replacement and inflammatory resorption may occur together in the one tooth. Replacement resorption cannot be treated effectively. Nevertheless, endodontic management may stop the progress of the inflammatory resorption by removing necrotic and infected pulp tissues but the replacement resorption once initiated, is generally progressive. The complications include: inflammatory root resorption, aesthetic compromise caused by disharmony of the smile due to a change in tooth position in the arch, orthodontic complications resulting from arch irregularity, lack of mesial drift, tilting of adjacent teeth, and arch length loss. Lack of sufficient alveolar bone may compromise future prosthetic solutions and may necessitate complex regenerative procedures in order to provide sufficient bone and soft tissue to support an aesthetic solution with an implant. To avoid such complications an ankylosed tooth should be removed before the changes become so pronounced that they compromise future prosthetic treatment. However extraction of an ankylosed tooth may involve vertical and horizontal loss of alveolar bone. To avoid such bone loss, a technique called decoronation, has been developed (Malmgren 2000). The crown of the tooth is removed and the ankylosed root is left in the alveolus to be substituted by bone. The height of the alveolar bone is thus improved vertically and preserved in the facio-lingual direction (Andreasen et al., 2007).

2.4.7 Factors affecting the prognosis of the avulsed teeth

It is now clear that viability of periodontal ligament will determine the prognosis of replanted teeth. Therefore, preservation of viable periodontal ligament is desirable. Andreasen, Pohl, Berman and others (Andreasen, 1981b, Pohl et al., 2005, Berman et al., 2007) have suggested that the presence of a viable periodontal ligament is the most important factor which might ensure healing with less root resorption. Consequently all efforts should be made to preserve the viability of periodontal ligament. This target must be considered the premier goal for the teeth that cannot be replanted immediately. As mentioned previously immediate replantation is not always possible at the time of the accident, and hence the tooth should be kept in a suitable medium until replantation can take place.

According to the literature the prognosis of avulsed teeth is partially determined by some external factors such as: extra alveolar time; storage media; time of pulp extirpation; root conditioning; contamination of the root surface; splinting; and use of an antibiotic.

2.4.7.1 Extra alveolar time

The extra alveolar time (EAT) has been regarded as the most important factor that could determine the prognosis of the replanted teeth. The longer the EAT the more likely is the loss of vitality of the periodontal ligament cells and subsequent incidence of root resorption. This is possibly due to the detrimental effect of cellular dehydration during the dry time (Andreasen 1981a, Caliskan et al., 2000,). In addition some other studies have gone further and considered the extended EAT as a good predictor of root resorption (Caliskan et al., 2000, Finucane and Kinirons 2003, Martins and Pileggi 2004). All these studies have shown that teeth which were kept dry sooner or later developed root resorption. Andreasen showed that there was a 95% chance of root resorption if the tooth has been out the mouth for more than 2 hours (Andreasen 1981a). Petrovic showed that a combination of delayed replantation and non physiological storage was certainly followed by high resorption rates and tooth loss (Petrovic et al., 2010). In summary, EAT has less effect on the outcomes when the tooth been stored in a suitable wet medium.

2.4.7.2 Storage media

It is desirable to replant an avulsed tooth immediately. However, in some situations immediate replantation is not possible and storage of an avulsed tooth in an appropriate storage medium is the only available option to ensure maximum viability of the cells of the periodontal ligament and cementum. Dry storage leads to cell necrosis and compromised healing (Andreasen 1981a). Experimental studies have indicated that the storage media, rather than the EAT determine the prognosis of the avulsed teeth (Andreasen et al., 2007).

Various storage media have been proposed in the literature for avulsed teeth. In most clinical cases avulsed teeth have been stored either in milk, tap water or normal saline. The storage medium should ideally maintain the vitality of the cells, since it is generally established that vital periodontal ligament cells are essential for favourable long term outcomes. Because the osmolarity of tap water may be detrimental to the viability of the cells it is not recommended as an appropriate storage media for avulsed teeth (Andreasen, 1981a, Andreasen et al., 1995b). Milk and saline have been recognised as good storage media in most experimental studies. Nevertheless saliva is recognized as a good media for shorter storage periods (Andreasen et al., 2007). These three media can keep the cells viable for about 2 hours without significantly impairing their healing potential (Andreasen 1981a, Blomlof 1981, Blomlof et al., 1983), while short dry storage periods had an adverse effect. Additional to that, some other studies showed Hanks Balanced Salt Solution (HBSS) to be the most suitable medium for storage as it could significantly preserve the viability of the cells during the extra oral period up to eight hours (Hiltz and Trope, 1991, Trope and Friedman, 1992). A recent review of storage media by Malhotra (Malhotra 2011) presented data for the use of other storage media:

Viaspan; Propolis; Culture media; Coconut water; Powdered milk; Egg albumin; Salvia officinalis; Morus rubra; and Emdogain. Malhotra concludes that HBSS remains the most optimal transport medium and further clinical and/or in vitro studies are required on these newer media before considering their usefulness and effectiveness in the case of an avulsed tooth.

2.4.7.3 Root conditioning:

During the last decade extensive research has been done trying to promote healing and to decrease root resorption using chemical agents. Many agents have been recommended to be applied to the root surface before replantation: alcohol; formalin; hypochloric acid; silicone grease; and methyl-methacrylate. Results have been equally unsatisfactory. Studies attempting to sterilize the root surface using acids and other caustic dressings have led to necrosis of any remaining vital cells and a consequent increase in the chance of root resorption (Chamberlin and Goerig 1980, Hammarstrom et al., 1986). One study suggested that the periodontal ligament should be removed when the extra alveolar time is more than 10 min (Grossman and Ship 1970). Conversely, another study suggested that this latter approach will increase the chance of root resorption. Klinge et al., suggested that Citric acid be used as a root conditioning agent aware of its action of removing non vital tissue remnants, thus allowing exposure of collagen that will facilitate the attachment of new fibrils from repairing periodontal ligament (Klinge et al., 1984).

It has also been suggested that soaking the avulsed tooth in tetracycline antibiotic and utilizing the antibacterial and anti resorptive properties of tetracycline would decrease the potential inflammation and would limit the area of root resorption. Together, tetracycline can promote fibroblast and connective tissue attachment and inhibit the osteoclast function (Baker et al., 1983, Golub et al., 1991). In addition other studies have indicated that using tetracycline could promote healing by decreasing the inflammatory root resorption with no decrease in replacement root resorption (Ma and Sae-Lim 2003). None of these studies validate the use of tetracycline as a root conditioning agent after avulsion and further research needs to be done in this area (Andreasen et al., 2007).

Emdogain (Enamel matrix proteins) has an unproven mode of action. It is suggested that it induces formation of acellular cementum and promotes periodontal ligament regeneration by stimulating proliferation of mesenchymal cells, thereby inhibiting proliferation of epithelial cells and promoting the secretion of certain growth factors. Some studies have advocated its use as a root conditioner and shown almost double the expected favourable root healing (Iqbal and Bamaas 2001). However, controversially Araujo (Araujo et al., 2003) failed to show any benefit in healing after soaking the avulsed tooth in Emdogain.

Finally, application of fluoride to the root surface before replantation has been recommended by some authors. It is postulated that the conversion of hydroxyapatite to fluoroapatite will offer more resistance to root resorption in addition to the inhibitory effect of the fluoride on odontoclast cells (Coccia, 1980, Hammarstrom et al., 1986, Bjorvatn et al., 1989, Selvig et al., 1990, Flores et al., 2001, Flores et al., 2007, Andersson et al., 2010).

2.4.7.4 Root surface contamination

In 1982 Lindskog and Blomlof noted the ability of bacteria to adhere to the periodontal ligament. Even if the avulsed tooth was stored in the patient's saliva, the viability of periodontal ligament cells might still be effected because of the lytic effect of bacterial enzymes and toxins (Lindskog and Blomlof 1982). Other interesting studies have been published which found that the extent of contamination of the root surface before replantation and the cleansing procedure prior to replantation have a significant effect on subsequent healing of periodontal ligament, and these studies highlighted the importance of a short rinse for avulsed teeth with tap water or saline before replantation (Andreasen et al., 1995a, Martin and Pileggi 2004, Kinirons et al., 2000). At the same time, it is recommended that all efforts are made to avoid any contamination of root surface, especially for immature teeth, in order to promote revascularization of the pulp (Cvek et al., 1990, Wang et al., 2010). Additionally it is suggested that if visible contamination is noted after placing the avulsed tooth in saline then the root surface should be rinsed with a stream of saline from a syringe until the visible contaminations have been washed away (Flores et al., 2007).

2.4.7.5 Splinting

It is desirable to support, maintain and immobilize replanted teeth using either a rigid or flexible splint with the purpose of stabilizing the avulsed tooth while healing of the periodontal ligament is taking place. One week is normally enough to ensure adequate periodontal support, as the majority of gingival marginal tissues are already healed by this time (Flores et al., 2007). However, according to the latest guideline recommendation (Flores et al., 2007) avulsed and replanted teeth should be splinted for two weeks with the exemption of very immature teeth with open apices where two to four weeks is recommended. Several clinical studies and experimental studies have shown that rigid and prolonged splinting might lead to an increase in the extent of root resorption especially replacement resorption. Non-rigid functional splinting allows physiological movement of replanted teeth and functional orientation of periodontal fibres. Functional movement during healing promotes healing with less ankylosis (Flores et al., 2007).

2.4.7.6 Timing of pulp access

According to the published guideline (Flores et al., 2007) on the management of avulsed teeth, it is advised that commencement of pulpal therapy should be based on the stage of root formation and the extra alveolar time. For teeth with open apices and a short extra alveolar time then pulpal extirpation should be postponed due to the possibility of pulpal revascularization unless there is clinical and radiographic evidence of pulpal necrosis. While for teeth with closed or almost closed apices, regardless of extra alveolar time, pulpal extirpation should be preformed as soon as the tooth is firm, usually just prior to splint removal. All these recommendations were based on the fact that delayed pulpal extirpation (at 20 days or later) resulted in acceleration of inflammatory root resorption (Kinirons et al., 1999). Direct communication of the periodontium with the necrotic pulp tissue through dentinal tubules after loss of cementum allows toxic materials to initiate inflammatory reactions in the periodontal ligament which subsequently stimulate the osteo-odontoclastic cells on the root surface (Andreasen 1981d, Andreasen 1985).

Removal of the infected pulp tissue, dressing with a proper root canal dressing such as Ledermix or calcium hydroxide paste and subsequent filling of the root canal with a root filling material will usually assist in termination of progress of the resorptive process (Andreasen et al., 2007, Berman et al., 2007). Delayed placement of root dressing until 10 to 14 days after replantation has been recommended to allow initial healing of periodontal tissues. This takes into consideration the negative effect on periodontal healing of the highly alkaline environment that might exist on the root surface after placement of a root dressing (Nerwich et al., 1993, Minana et al., 2001, Ho et al., 2003).

2.4.7.7 Use of systemic antibiotic

Current literature is still inconclusive. There is no evidence of an association between systemic antibiotic therapy and promotion or enhancement of periodontal healing (Hinckfuss and Messer 2009), and it is questionable whether systemic antibiotic should be prescribed at the emergency time of dental avulsion or not. However, prescribing of systemic antibiotic therapy is generally recommended when replanting avulsed teeth (Welbury and Gregg 2006, Flores et al., 2007). In particular, when there was contamination of the tooth and/or supporting tissues it is assumed that a systemic antibiotic might help to reduce the risk of infection and subsequent root resorption. Additionally some other studies have gone further and advised topical application of antibiotic to the tooth surfaces e.g; by soaking the avulsed tooth in an antibiotic such as doxycyline for 5 min before replantation. This might help increase the chance of revascularization, especially for immature teeth, and at the same time it could help to decrease the bacterial contamination and subsequent root resorption (Berman et al., 2007).

Chapter III – Paediatric Facial Injuries in Scotland

3.1 Abstract

Background: Paediatric facial injury can lead to significant morbidity. Socio-demographic determinants in Scotland have not previously been reported.

Aim: To describe, analyse, and report the epidemiology, pattern, time trends, and key sociodemographic determinants in children and adolescents who have suffered facial injury requiring in-patient care.

Method: Scottish Morbidity records for all hospital stays for the period 2001-2009 were retrieved from the Information Services Division in Scotland (ISD): Annual incidences were calculated by age, gender, Health Board, Scottish Index of Multiple Deprivation (SIMD) and mechanism of injury. A Poisson regression model was used to incorporate the study variables.

Results: 45,388 (0.5%) of 9,568,185 aged 0 - 17 years (over nine years) sustained a facial injury (4.7 per 1000 population). 60% of injuries were due to non-intentional injury, 15% to motor vehicle incidents, and 9% to assault. 4.5% were alcohol related. The incidence decreased over time from 5.5/1000 in 2001 to 4.0/1000 in 2009. The risk ratio (RR) for males was 1.98 times greater than females ($p < 0.001$). RR varied significantly between Health Board Areas from 0.68 (Dumfries and Galloway) to 1.76 (Grampian) ($p < 0.001$). There was a significant association between facial injury and deprivation ($p<0.001$); SIMD 1 (most deprived) had the highest incidence (6.3 per 1000 population; RR =1.89).

Conclusion: This study is the first and the largest undertaken to report the pattern, time trends, and key socio-demographic determinants of paediatric facial injury in Scotland. Among the Scottish paediatric population the incidence and rate ratio of facial injury is higher in males living in areas of social deprivation, and in certain geographical areas of Scotland. Many

injuries are due to non-intentional injury and more needs to be done to direct education and resources toward prevention for young people living in areas of multiple social deprivation.

3.2 Introduction

Several studies have been published internationally on the epidemiology of facial injury in paediatric populations and they report a prevalence of 1% to 15% (Haug and Foss 2000, Levin et al., 2010, Kidd et al., 2010). This suggests that although facial injury is less common in childhood it is still a significant cause of morbidity and presentation to hospital emergency departments (Zerfowski and Bremerich 1998, Hogg et al., 2000, Shaikh and Worrall 2002, Gassner et al., 2004, Islam et al., 2006, Rahman et al., 2007, Eggensperger et al., 2008, Imahara et al., 2008, Vyas et al., 2008, Al-Malik, 2009, Levin et al., 2010, Kidd et al., 2010). The causes of facial injury in childhood would appear to be multifactorial with mechanisms of injury including falls, interpersonal violence, motor vehicle incidents and other non-intentional causes. More recently the pattern, magnitude, time trends, and key socio-demographic determinants of facial injuries in Scottish adults admitted to hospital have been reported (Conway et al., 2010). There was a clear and significant association with socio-economic deprivation. At the same time, another study has questioned the prevalence of such facial injuries in children and adolescents (Kidd et al., 2010). However, the socio-demographic determinants of facial injuries in the paediatric population in Scotland have not previously been reported and the question of whether such injuries are equally distributed across all socio-economic groups has not been answered.

This chapter aims to describe, analyse and report the epidemiology, pattern, time trends, and key socio-demographic determinants in children and adolescents with facial injuries requiring in-patient hospital admission in Scotland between 2001 and 2009. Section 3.3 of this chapter will cover the aims and objectives of this study. Methods adopted to achieve these aims and objectives will be presented in Section 3.4. The results will be demonstrated in Section 3.5 and the discussion and conclusion of this study in Sections 3.6 and 3.7.

3.3 Aims and Objectives

By looking at data pertaining to children and adolescents who had sustained facial Injury in Scotland between 2001 and 2009 requiring in-patient care, this part of the research aims to:

- Identify the demographics of facial injury in Scotland
- Investigate the characteristics and trends of facial injuries over time in Scotland
- Assess whether differences in socio-demographics exist between facial injury cases
- Document the length and trends of hospital stay of identified cases over the study period
- Determine the prevalence of facial injuries associated with interpersonal violence, motor vehicle incidents, and other non-intentional events
- Examine the trend of alcohol-related facial injury and to assess whether alcohol consumption was an associated factor with facial injury in this group

3.4 Methods

3.4.1 Study setting

Scotland is a country covering an area of around 78,782 square kilometres (30,418 sq mi). Much of the population live in urban centres such as Greater Glasgow and Edinburgh, which are the areas of highest population density within Scotland, but some also reside in the very remote areas of the Scottish Highlands and Islands which have the lowest population density. Scotland currently has fourteen National Health Service (NHS) Boards (Figure 3. 1):

1. Ayrshire and Arran
2. Borders
3. Dumfries and Galloway
4. Western Isles
5. Fife
6. Forth Valley
7. Grampian
8. Greater Glasgow and Clyde
9. Highland
10. Lanarkshire
11. Lothian
12. Tayside
13. Shetland
14. Orkney

These fourteen NHS Boards cover specific geographical territories. The role of NHS Boards is the improvement of health for the resident population by developing a local health plan, together with responsibility for operational issues through its operating divisions.

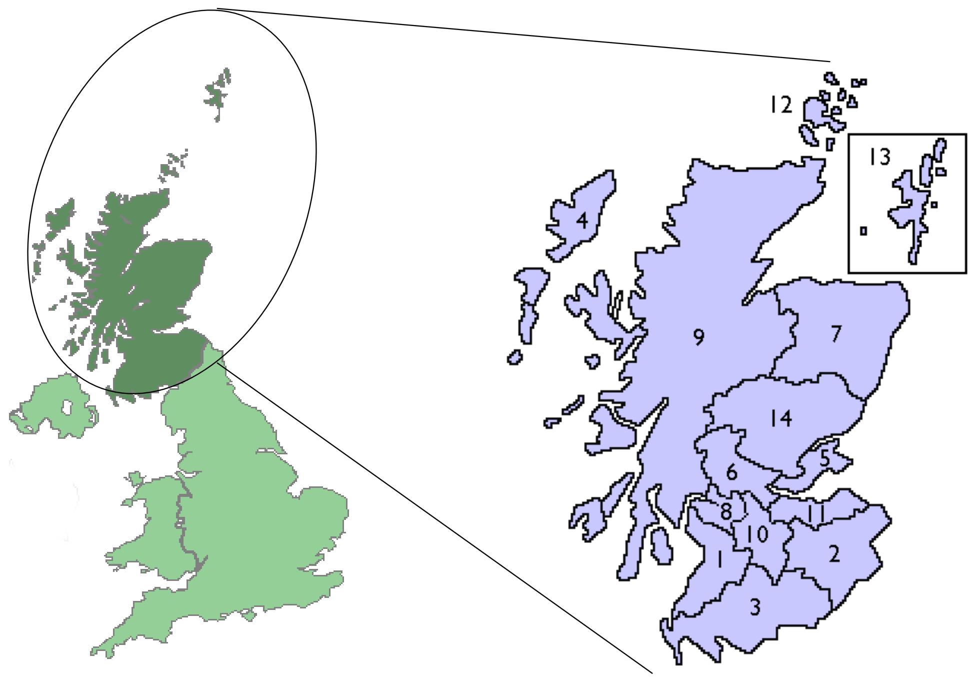


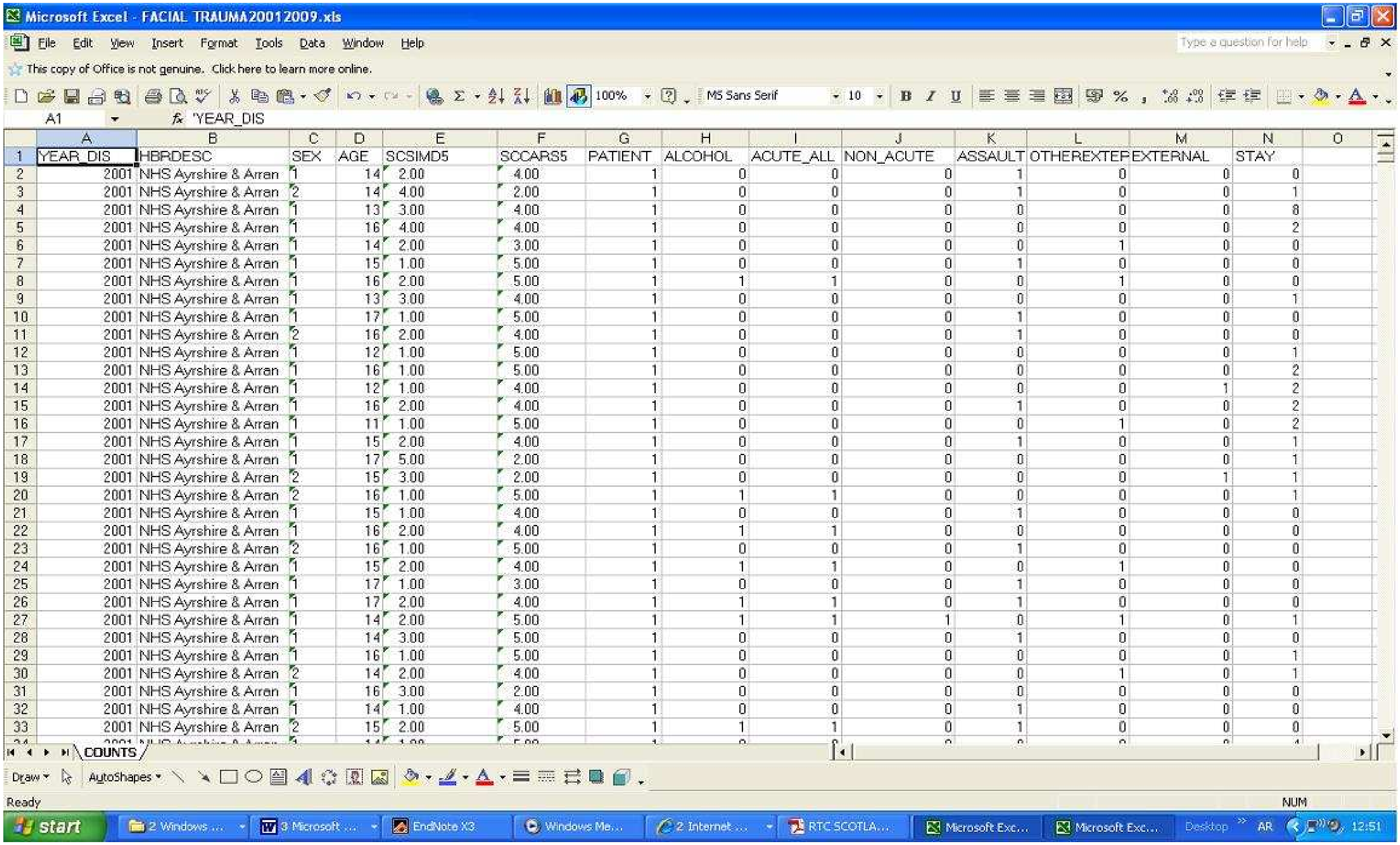
Figure 3. 1 Map of the UK on the left. Map of Scotland with Health Board borders and location on the right

3.4.2 Data sources

3.4.2.1 NHS Hospitalisation Records: Scottish Morbidity Records 01 (SMR01)

The Information Services Division in Scotland (ISD) has been in existence for over forty-three years 'since 1968' providing a consistently high quality national coverage of data (ISD- Scotland 2010). Scottish morbidity records (SMR) data have been collected since that time and are one of the world's first and most complete national health data sets. SMR data are used for both epidemiological monitoring and NHS management purposes. The in-patient records (SMR01, non-obstetric and non-psychiatric) are recorded in Scotland for each new hospital admission (ISD Scotland-SMR 2010). This incorporates the international classification of diseases (ICD-10), which comprise the external code for identifying facial injured patients and injury classification (Appendix 2). Episode management and clinical information in addition to demographic data such as age, gender, admission, and discharge dates and address of residence including postcode is also recorded. Supplementary diagnostic codes are also recorded, allowing retrieval of information concerning factors such as causes and alcohol involvement (Table 2-5 in Appendix 2).

Initially, the Information and Statistics Division (ISD) of the NHS National Services Scotland (NHS NSS) was contacted regarding accessing data on facial injury. Data were requested electronically, utilising a pre-formed data collection sheet based on the information available in the ISD (Figure 3. 2). The Scottish Morbidity records (SMR01) for the period 2001-2009 were retrieved. All data was anonymised and no ethical approval was required. The study included all hospitalised facial injury casualty-records from SMR01, for all the area of Scotland. The complete and valid data of SMR01 Records with a diagnostic code of facial injury were available up to the end of 2009.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	YEAR_DIS	HBRDESC	SEX	AGE	SCSIMD5	SCCARS5	PATIENT	ALCOHOL	ACUTE_ALL	NON_ACUTE	ASSAULT	OTHEREXTEF	EXTERNAL	STAY
2	2001	NHS Ayrshire & Arran	1	14	2.00	4.00	1	0	0	0	1	0	0	0
3	2001	NHS Ayrshire & Arran	2	14	4.00	2.00	1	0	0	0	1	0	0	1
4	2001	NHS Ayrshire & Arran	1	13	3.00	4.00	1	0	0	0	0	0	0	8
5	2001	NHS Ayrshire & Arran	1	16	4.00	4.00	1	0	0	0	0	0	0	2
6	2001	NHS Ayrshire & Arran	1	14	2.00	3.00	1	0	0	0	0	1	0	0
7	2001	NHS Ayrshire & Arran	1	15	1.00	5.00	1	0	0	0	1	0	0	0
8	2001	NHS Ayrshire & Arran	1	16	2.00	5.00	1	1	1	0	0	1	0	0
9	2001	NHS Ayrshire & Arran	1	13	3.00	4.00	1	0	0	0	0	0	0	1
10	2001	NHS Ayrshire & Arran	1	17	1.00	5.00	1	0	0	0	1	0	0	0
11	2001	NHS Ayrshire & Arran	2	16	2.00	4.00	1	0	0	0	1	0	0	0
12	2001	NHS Ayrshire & Arran	1	12	1.00	5.00	1	0	0	0	0	0	0	1
13	2001	NHS Ayrshire & Arran	1	16	1.00	5.00	1	0	0	0	0	0	0	2
14	2001	NHS Ayrshire & Arran	1	12	1.00	4.00	1	0	0	0	0	0	1	2
15	2001	NHS Ayrshire & Arran	1	16	2.00	4.00	1	0	0	0	1	0	0	2
16	2001	NHS Ayrshire & Arran	1	11	1.00	5.00	1	0	0	0	0	1	0	2
17	2001	NHS Ayrshire & Arran	1	15	2.00	4.00	1	0	0	0	1	0	0	1
18	2001	NHS Ayrshire & Arran	1	17	5.00	2.00	1	0	0	0	0	0	0	1
19	2001	NHS Ayrshire & Arran	2	15	3.00	2.00	1	0	0	0	0	0	1	1
20	2001	NHS Ayrshire & Arran	2	16	1.00	5.00	1	1	1	0	0	0	0	1
21	2001	NHS Ayrshire & Arran	1	15	1.00	4.00	1	0	0	0	1	0	0	0
22	2001	NHS Ayrshire & Arran	1	16	2.00	4.00	1	1	1	0	0	0	0	0
23	2001	NHS Ayrshire & Arran	2	16	1.00	5.00	1	0	0	0	1	0	0	0
24	2001	NHS Ayrshire & Arran	1	15	2.00	4.00	1	1	1	0	0	1	0	0
25	2001	NHS Ayrshire & Arran	1	17	1.00	3.00	1	0	0	0	1	0	0	0
26	2001	NHS Ayrshire & Arran	1	17	2.00	4.00	1	1	1	0	1	0	0	0
27	2001	NHS Ayrshire & Arran	1	14	2.00	5.00	1	1	1	1	0	1	0	1
28	2001	NHS Ayrshire & Arran	1	14	3.00	5.00	1	0	0	0	1	0	0	0
29	2001	NHS Ayrshire & Arran	1	16	1.00	5.00	1	0	0	0	0	0	0	1
30	2001	NHS Ayrshire & Arran	2	14	2.00	4.00	1	0	0	0	0	1	0	1
31	2001	NHS Ayrshire & Arran	1	16	3.00	2.00	1	0	0	0	0	0	0	0
32	2001	NHS Ayrshire & Arran	1	14	1.00	4.00	1	0	0	0	1	0	0	0
33	2001	NHS Ayrshire & Arran	2	15	2.00	5.00	1	1	1	0	1	0	0	0

Figure 3. 2 Electronic Data Set

3.4.3 Evaluation of Deprivation

Deprivation is a concept that is widely used in public health research. According to the literature facial injuries and their sequelae would appear to be highly correlated with deprivation, and as Scotland includes regions that are considered to be some of the most deprived regions in the UK, it is of great importance to include a measure of deprivation in any study of public health in this location.

In this part of the research the primary measure of neighbourhood deprivation used was the recently developed Scottish Index of Multiple Deprivation 'SIMD – 2009' (SIMD-SCOT.GOV. 2010), which was created by the Scottish Executive (Government) for monitoring and planning purposes. Deprivation scores were calculated by linking subjects' postcodes data from SMR01 records with the Scottish Index of Multiple Deprivation (SIMD-2009) and resulted in the ability to distinguish levels of deprivation between areas of Scotland. This was achieved by recording the levels of deprivation for small geographic areas (data zones) which were ranked from 1 (most deprived) to 6505 (least deprived), where the level of deprivation in each domain was calculated on the basis of a range of indicators. The overall levels of deprivation are then calculated on the basis of weighting and combining the individual deprivation domains. The weighting for each domain is based on the relative importance of the domain in measuring multiple deprivation. The domain weightings used in SIMD 2009, expressed as a percentage of the overall weight are: current income (28%); employment (28%); health (14%); education (14%); geographic access (9%); crime (5%); and housing (2%) (SIMD-SCOT.GOV. 2010).

3.4.4 Study sample

The targeted population who were included in this part of the research were all children and adolescents up to and including 17 years of age with a facial injury who were coded as presenting to the emergency departments and requiring in-patient care in NHS hospitals in Scotland between 2001 and 2009.

Population estimates in all Scotland regions were obtained from the General Register Office for Scotland (GROS) for 2001-2009. Population denominators were used in calculating casualty rates per 1,000 population.

3.4.5 Length of stay

The length of stay in hospital is calculated in whole days i.e. if the person was admitted on the 27th of a month and discharged on the same day the length of stay would be <24 hours. If the person was admitted on the 27th of a month and discharged on the 28th in the same month, the length of stay would be one day. To examine length of stay the days were grouped as follows: <24 hours; 1-3 days; 4-10 days; 11-21 days; 22-45 days; 46-90 days; and >90 days.

3.4.6 Statistical analysis

All incidence rates were reported per 1,000 population at risk. Annual incidence rates by time (year), age, gender, Health Board, SIMD and aetiology were calculated for the period of the study. Overall, the incidence rates for all ages were ranked separately and then the associations between the injury rates, area of deprivation, alcohol involvement, and leading causes were examined. Risk ratios with 95% confidence intervals were estimated. All rates were calculated using population data for each targeted year population. Estimates were derived from the Annual Reports of the Registrar General for Scotland for corresponding years.

After discussion and consultation with the statistician, Poisson regression models were used to incorporate the study variables and to assess the significance of trends in incidence for each variable. Poisson regression was also used to model the incidence trends where univariate and multivariate analyses were carried out. In order to assess the relationship between deprivation and paediatric facial injury incidence over time and to test the significance of any differences a multilevel Poisson regression analysis model was used by incorporating the study variables; age, gender, time (year), and deprivation quintile (SIMD). The univariate effects of gender, age, time and deprivation were examined as categorical variables. All the statistical analysis for this part of the research was conducted using the SAS statistical software package version 9.1 (SAS Institute Inc. Cary, NC, USA).

3.5 Results

3.5.1 Data generated and its description

3.5.1.1 Study variables and demographic information

Between 2001 and 2009, a total of 45388 (0.5%) of 9,568,185 persons aged 0 to 17 years were recorded with a diagnosis of facial injury, with an overall incidence rate of 4.7 per 1000 population (Table 3. 1). An incidence of 6.21 per 1000 population was recorded for males (30434 patients) and 3.20 per 1000 population for females (14954 patients) (Table 3. 2).

Table 3. 1 Incidence rate of facial injuries in Scotland 2001-2009

Total Pop^n (0-17 Yrs) (2001-2009)		Total Events (2001-2009)	
9568185		45388	
Total Pop^n	**Events_Sum**	**Pop^n_1000**	**Rate**
9568185	45388	9568.19	4.74

Table 3. 2 Events of facial injuries by patient's gender

Gender	*n*, of events (%)	Pop^n_1000	Rate
Female	14954 (32.9)	4668.37	3.20
Male	30434 (67.1)	4899.82	6.21
Total	45388(100)		

Patients' ages at time of injury were considered. With a range of 0 to 17 years of age, facial injury showed peaks of incidence at the extremes of age. Those aged <3 years of age and those at >15 years had high incidence rates of facial injury compared to other ages as shown in (Table 3. 3).

Table 3. 3 Events of facial injuries by patient's age

Age	*n*, of events (%)	Pop^n_1000	Rate
0	3568 (7.9)	494.30	7.22
1	4144 (9.1)	490.07	8.46
2	3241 (7.1)	487.53	6.65
3	2489 (5.5)	488.27	5.10
4	2261 (5.0)	492.32	4.59
5	2200 (4.8)	495.88	4.44
6	1955 (4.3)	501.53	3.90
7	1870 (4.1)	510.55	3.66
8	1778 (3.9)	521.77	3.41
9	1766 (3.9)	534.24	3.31
10	1835 (4.0)	546.31	3.36
11	1859 (4.1)	554.31	3.35
12	2233 (4.9)	560.25	3.99
13	2240 (4.9)	567.15	3.95
14	2434 (5.4)	573.53	4.24
15	2845 (6.3)	579.91	4.91
16	3122 (6.9)	585.12	5.34
17	3548 (7.8)	585.14	6.06
Total	45388(100)		

In accord with the aims and the methodology of this study, the Scottish Index of Multiple Deprivation (SIMD) was observed for each recruited case. The rate of incidence was very high, 6.34/1000 and 5.15/1000, for those who were living in the most deprived areas (SIMD 1 and SIMD 2) (Table 3. 4).

Table 3. 4 Events of facial injuries according to SIMD

SIMD	*n*, of events (%)	Pop^n_1000	Rate
1	13520 (29.8)	2133.09	6.34
2	9589(21.1)	1863.09	5.15
3	7890(17.4)	1818.40	4.34
4	7233(15.9)	1837.34	3.94
5	7156(15.8)	1916.27	3.73
Total	45388 (100)		

The incidence rates for sustaining facial injury in each NHS Health Board (area) were documented and were varied. The highest rate was reported in Grampian NHS Health Board (7.1/1000 population) (Table 3. 5).

Table 3. 5 Events of facial injuries according to Health Board (area)

Health Board	*n*, of events (%)	Pop^n_1000	Rate
NHS Ayrshire & Arran	3710 (8.2)	694.28	5.34
NHS Borders	1114 (2.5)	205.45	5.42
NHS Dumfries & Galloway	814 (1.8)	268.78	3.03
NHS Fife	3262 (7.2)	679.44	4.80
NHS Forth Valley	2487 (5.5)	556.34	4.47
NHS Greater Glasgow & Clyde	10345 (22.8)	2220.29	4.66
NHS Grampian	7015 (15.5)	986.66	7.11
NHS Highland	2358 (5.2)	570.11	4.14
NHS Lanarkshire	4556 (10.0)	1107.65	4.11
NHS Lothian	6261 (13.8)	1432.14	4.37
NHS Orkney Islands	154 (0.3)	37.50	4.11
NHS Shetland Islands	207 (0.5)	46.15	4.48
NHS Tayside	2872 (6.3)	714.69	4.02
NHS Western Isles	233 (0.5)	48.72	4.78
Total	45388 (100)		

The incidence rates for sustaining facial injury requiring in-patient care in the paediatric population in Scotland were observed for each year from 2001-2009. The incidence rate has declined over time from 5.5 per 1000 population in 2001 to 4.0 per 1000 population in 2009 (Table 3. 6).

Table 3. 6 Events of facial injuries over study period (2001-2009)

Study period (Year)	*n*, of events (%)	Pop^n_1000	Rate
2001	5984 (13.2)	1097.61	5.45
2002	5796 (12.8)	1085.80	5.34
2003	5384 (11.9)	1073.67	5.01
2004	5137 (11.3)	1066.65	4.82
2005	5096 (11.2)	1059.03	4.81
2006	4987 (11.0)	1050.19	4.75
2007	4631 (10.2)	1047.41	4.42
2008	4197 (9.2)	1045.69	4.01
2009	4176 (9.2)	1042.15	4.01
Total	45388 (100)		

3.5.1.2 Trends of facial injuries over time by study variables

3.5.1.2.1 Trends of facial injury over time by age

The trends of facial injury over the period of the study with respect to the age of the patients were noticed to have decreased over time, but those who were at the extremes of age (< 2 and >15) still sustained the most injuries (Table 3. 7 and Figure 3. 3).

Table 3. 7 Trends (Numbers) of facial injuries over time by patient's age

Age	Date of injury									Total
	2001	2002	2003	2004	2005	2006	2007	2008	2009	
0	368	423	394	415	448	442	331	357	390	3568
1	470	500	459	467	470	479	430	455	414	4144
2	399	395	373	315	355	352	359	340	353	3241
3	315	328	267	255	270	274	262	270	248	2489
4	326	295	270	246	260	228	213	210	213	2261
5	321	312	278	232	240	237	197	178	205	2200
6	286	256	252	235	248	197	177	147	157	1955
7	243	241	257	242	220	183	169	155	160	1870
8	246	242	213	201	193	185	181	161	156	1778
9	263	233	221	211	194	172	175	140	157	1766
10	292	266	235	214	182	174	178	147	147	1835
11	280	258	199	247	210	192	184	146	143	1859
12	337	286	300	276	252	246	206	163	167	2233
13	283	308	274	277	276	232	233	171	186	2240
14	326	331	260	267	293	280	263	211	203	2434
15	386	332	364	304	292	330	322	273	242	2845
16	427	377	350	364	330	358	355	269	292	3122
17	416	413	418	369	363	426	396	404	343	3548
Total	5984	5796	5384	5137	5096	4987	4631	4197	4176	45388

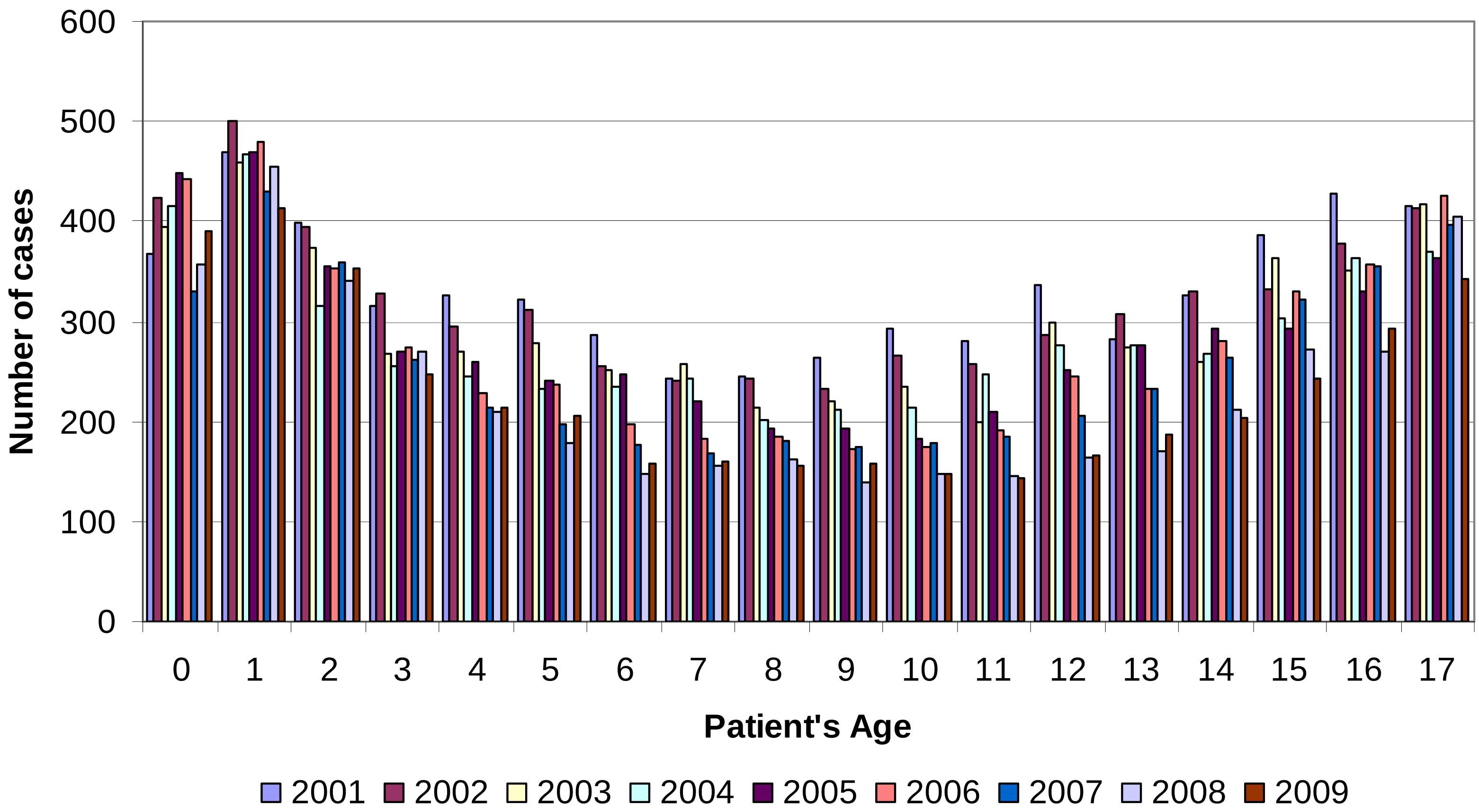


Figure 3. 3 Trends of facial injuries over time by patient’s age

3.5.1.2.2 Trends of facial injury over time by gender

Table 3. 8 and Figure 3. 4 show the trends and number of male and female patients admitted for treatment of facial injury over the study period. Both genders recorded a reduction in the number of cases over time. However males still had the highest admissions over the study period (M: F = 2: 1).

Table 3. 8 Trends (Number) of facial injuries over time by patient's gender

Year	Patient Gender		Total
	Male	Female	
2001	4028	1956	5984
2002	3883	1913	5796
2003	3635	1749	5384
2004	3501	1636	5137
2005	3423	1673	5096
2006	3321	1666	4987
2007	3130	1501	4631
2008	2767	1430	4197
2009	2744	1432	4176
Total	30432	14956	45388

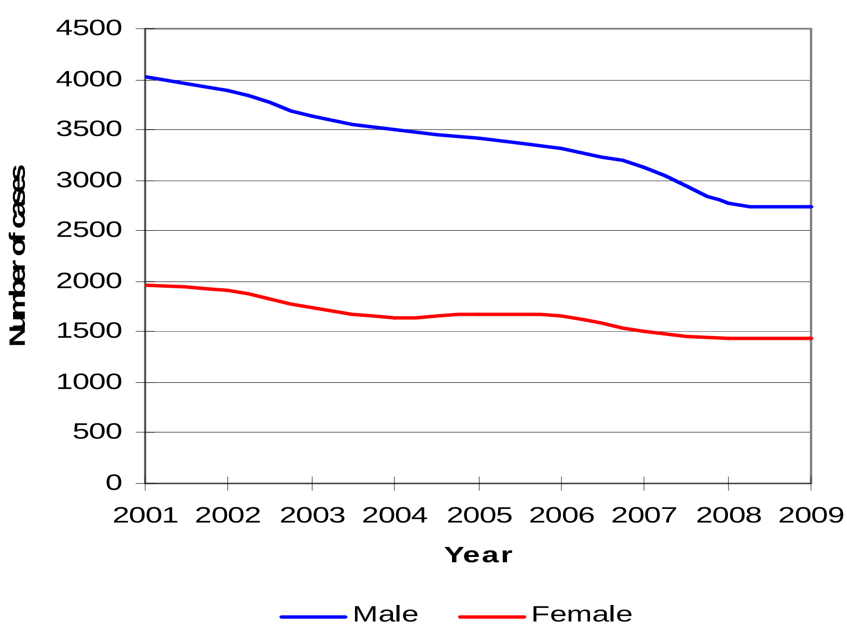


Figure 3. 4 Trends of facial injuries over time by patient's gender

3.5.1.2.3 Trends of facial injury over time by SIMD

Those sustaining facial injury over the period of the study with respect to the Scottish Index of Multiple Deprivation (SIMD) are shown in Table 3. 9 and Figure 3. 5. Despite an overall reduction in the total number of cases, those in the most deprived areas (SIMD 1 and SIMD 2) still suffered more injuries than those who live in the least deprived areas.

Table 3. 9 Trends (Number) of facial injuries over time by SIMD

Year	SIMD					Total
	SIMD 1	SIMD 2	SIMD 3	SIMD 4	SIMD 5	
2001	1889	1293	1005	911	886	5984
2002	1770	1212	1037	874	903	5796
2003	1633	1173	896	814	868	5384
2004	1497	1121	883	817	819	5137
2005	1541	1045	868	832	810	5096
2006	1512	1026	851	830	768	4987
2007	1346	939	813	794	739	4631
2008	1208	864	764	684	677	4197
2009	1124	916	773	677	686	4176
Total	13520	9589	7890	7233	7156	45388

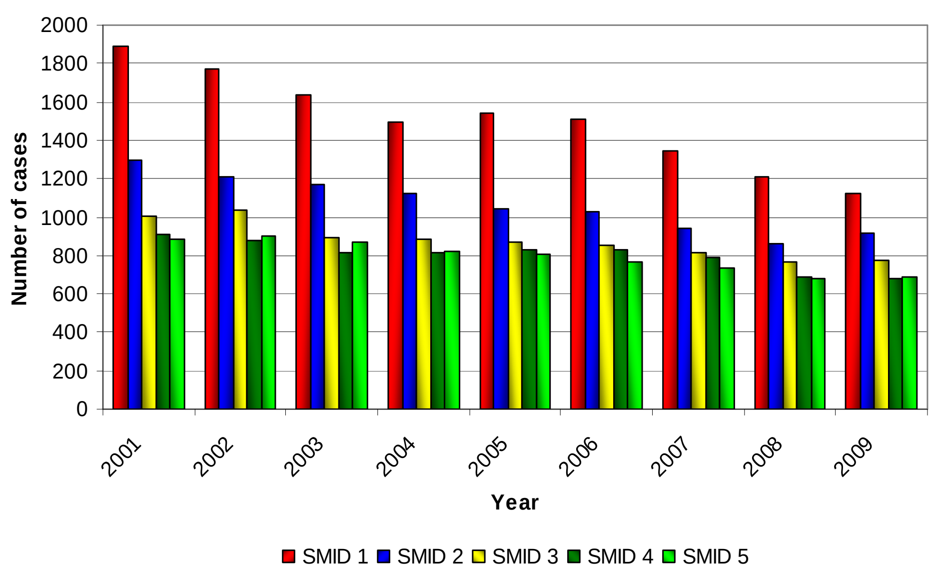


Figure 3. 5 Trends of facial injuries over time by SIMD

3.5.1.2.4 Trends of facial injuries over time by length of stay (hospital admission)

There was a large reduction in the length of stay among those who were required to stay in hospital between 1-3 days over the period of study. However, the figure remained almost the same for those who were sent home in <24 hours of admission. In comparison, fewer cases were required to stay in hospital for more than three days (Table 3. 10 and Figure 3. 6).

Table 3. 10 Trends (Number) of facial injuries over time by length of stay in hospital

Year	Length of stay							Total
	< 24 Hours	1 - 3 Days	4 - 10 Days	11 - 21 Days	22 - 45 Days	46 - 90 Days	>90 Days	
2001	1963	3790	177	35	13	6	0	5984
2002	2000	3583	157	31	19	5	1	5796
2003	1990	3184	151	35	17	6	1	5384
2004	2037	2917	137	31	11	1	3	5137
2005	2133	2803	119	32	3	3	3	5096
2006	2310	2527	104	27	13	5	1	4987
2007	2209	2281	105	17	14	4	1	4631
2008	2045	2027	97	20	7	1	0	4197
2009	2099	1966	96	9	5	0	1	4176
Total	18786	25078	1143	237	102	31	11	45388

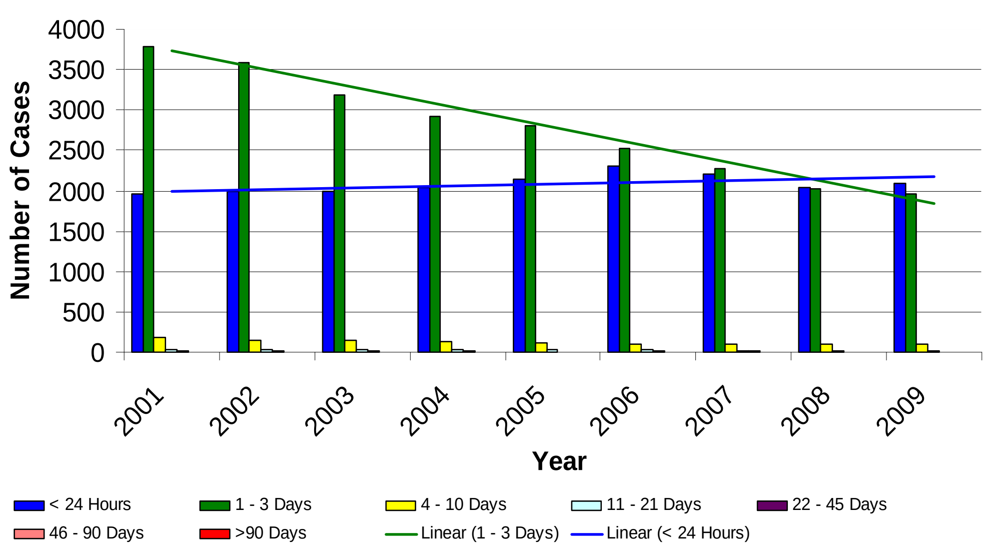


Figure 3. 6 Trends of facial injuries over time by length of stay in hospital

3.5.1.3 Aetiology

3.5.1.3.1 Interpersonal violence

Analysis of the data revealed that four thousand one hundred and forty-nine (9.1%) patients had suffered a facial injury caused by interpersonal violence (Table 3. 11 and Figure 3. 7). The majority of the cases (83.3 %, 3455 cases) were males (M: F = 5: 1) (Table 3. 12 and Figure 3. 8).

Table 3. 11 Trends of facial injuries - Interpersonal violence related

Interpersonal violence	Frequency	%
No	41239	90.9
Yes	4149	9.1
Total	45388	100.0

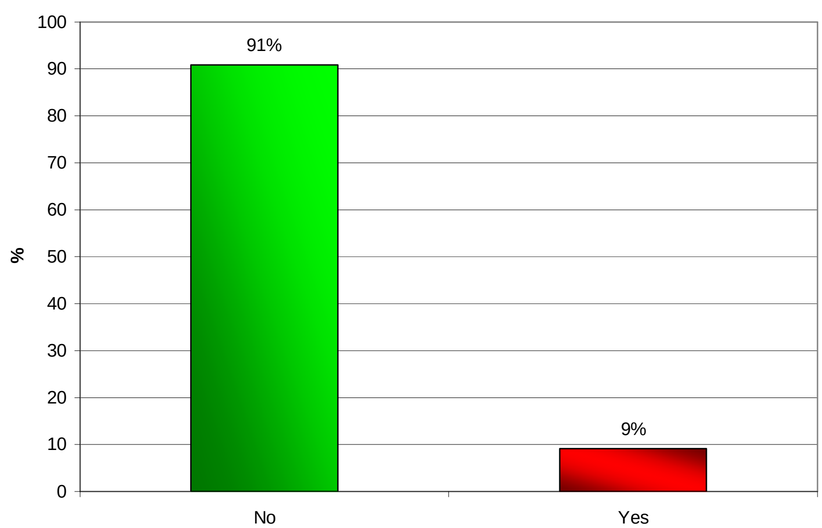


Figure 3. 7 Proportion of facial injuries: Interpersonal violence related

Table 3. 12 Interpersonal violence related facial injuries - trends over time by gender

Interpersonal violence	Date of injury	Patient Gender		Total
		Male	Female	
Yes	2001	437	87	524
	2002	427	75	502
	2003	427	76	503
	2004	423	81	504
	2005	387	78	465
	2006	432	97	529
	2007	367	73	440
	2008	292	74	366
	2009	263	53	316
Total		3455	694	4149

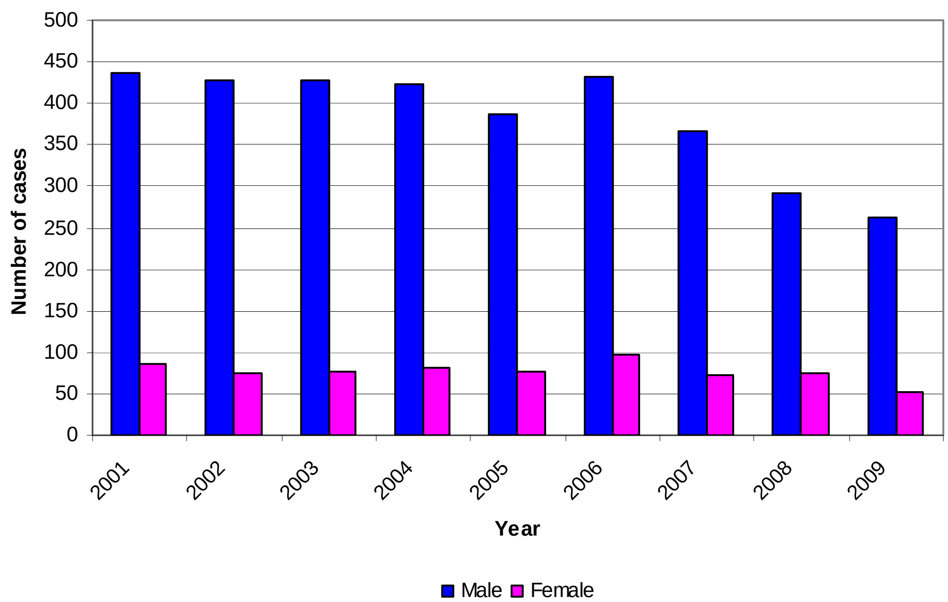


Figure 3. 8 Interpersonal violence related facial injuries - trends over time by gender

In respect to the patient age, the proportion of facial injuries due to interpersonal violence remained almost the same during the study period (Table 3. 13 and Figure 3. 9). However, there was a constant association between older age and facial injuries sustained due to interpersonal violence. Similarly there was a much smaller but still constant association between injuries sustained by interpersonal violence and those who were under two years of age at the time of injury (Table 3. 14 and Figure 3. 10).

Table 3. 13 Proportion of facial injuries; Interpersonal violence related- trends over time

	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Cases (*n*)	524	502	503	504	465	529	440	366	316	4149
%	8.76	8.66	9.34	9.81	9.12	10.61	9.5	8.72	7.57	9

Table 3. 14 Interpersonal violence related facial injuries-trends over time by patient's age

	Patient Age	Date of injury									Total
		2001	2002	2003	2004	2005	2006	2007	2008	2009	
Yes	0	15	9	9	10	5	3	7	11	13	82
	1	5	5	4	6	3	5	5	6	0	39
	2	3	5	4	1	6	2	2	2	3	28
	3	3	3	2	1	1	0	1	1	0	12
	4	0	1	2	1	1	0	1	1	0	7
	5	5	3	2	1	1	0	0	1	1	14
	6	2	3	0	1	0	3	0	0	0	9
	7	4	2	1	0	1	1	0	0	0	9
	8	2	2	2	0	1	1	2	1	1	12
	9	4	2	4	3	3	2	2	0	1	21
	10	5	4	4	6	5	1	4	1	0	30
	11	8	9	7	8	9	5	6	1	1	54
	12	22	17	19	18	20	21	21	6	6	150
	13	26	38	35	37	28	29	25	21	21	260
	14	69	48	51	56	72	67	50	41	33	487
	15	82	91	92	89	83	104	87	69	55	752
	16	133	122	120	128	103	120	100	71	73	970
	17	136	138	145	138	123	165	127	133	108	1213
	Total	524	502	503	504	465	529	440	366	316	4149

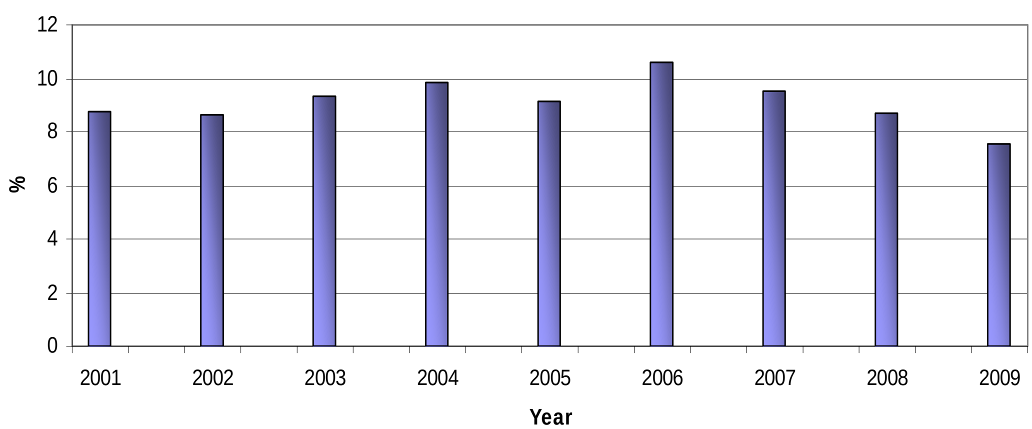


Figure 3. 9 Proportion of facial injuries; Inter personal violence related- trends over time

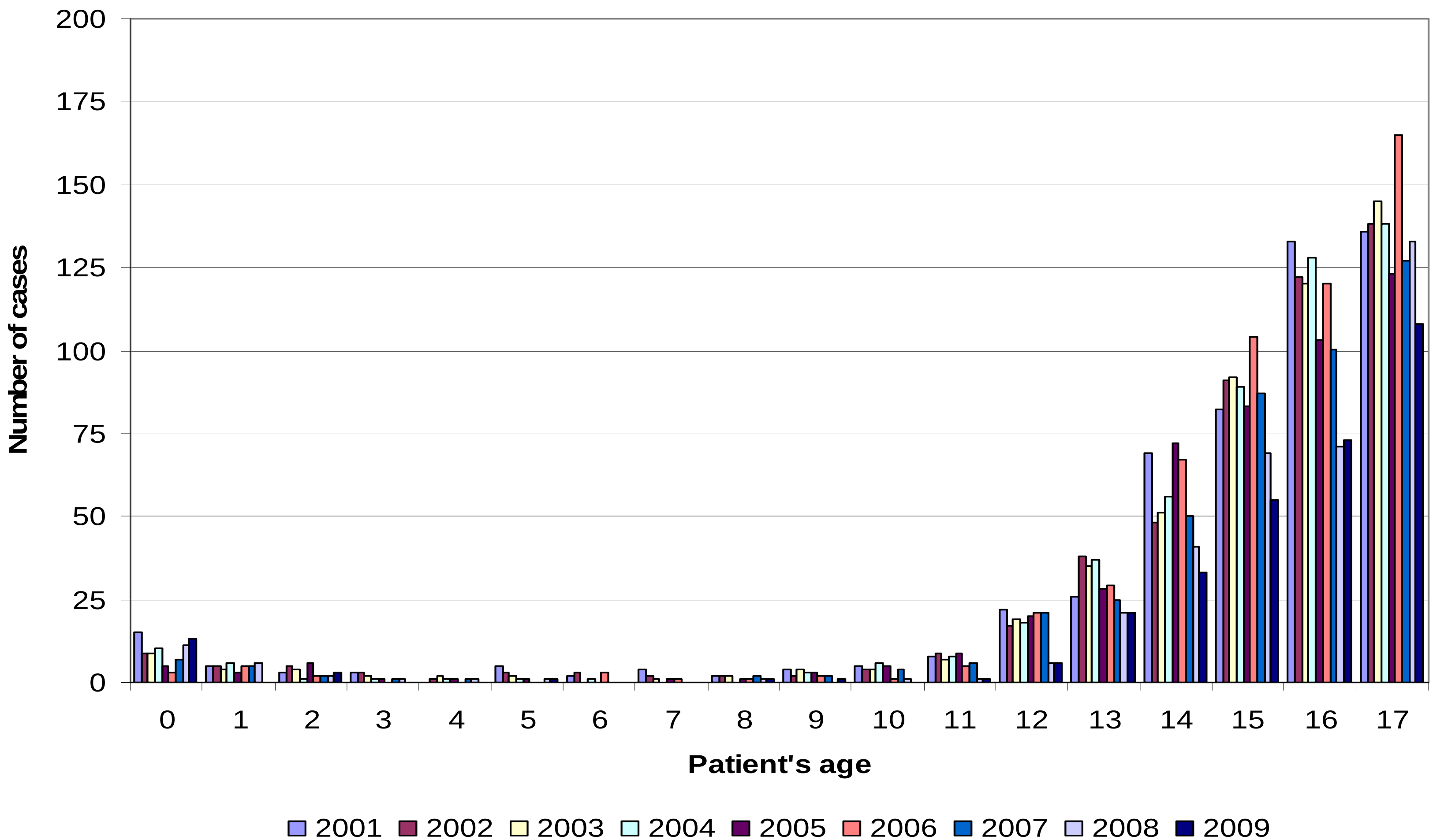


Figure 3. 10 Interpersonal violence related facial injuries; trends over time by patient's age

Analysis of association between the level of deprivation and having a facial injury as a result of interpersonal violence shows that the majority of cases were sustained by those who were living in the most deprived areas (SIMD 1 and SIMD 2 areas) compared to those in the last deprived areas (Table 3. 15 and Figure 3. 11).

Table 3. 15 Interpersonal violence related facial injuries; trends over time by SIMD

	Date of trauma		SIMD					Total
			SIMD 1	SIMD 2	SIMD 3	SIMD 4	SIMD 5	
Yes	2001		239	128	63	54	40	524
		%	45.6%	24.4%	12.0%	10.3%	7.6%	100.0%
	2002		219	118	83	53	29	502
		%	43.6%	23.5%	16.5%	10.6%	5.8%	100.0%
	2003		201	130	74	49	49	503
		%	40.0%	25.8%	14.7%	9.7%	9.7%	100.0%
	2004		215	127	77	53	32	504
		%	42.7%	25.2%	15.3%	10.5%	6.3%	100.0%
	2005		173	90	83	71	48	465
		%	37.2%	19.4%	17.8%	15.3%	10.3%	100.0%
	2006		204	121	85	75	44	529
		%	38.6%	22.9%	16.1%	14.2%	8.3%	100.0%
	2007		180	104	68	48	40	440
		%	40.9%	23.6%	15.5%	10.9%	9.1%	100.0%
	2008		148	69	72	40	37	366
		%	40.4%	18.9%	19.7%	10.9%	10.1%	100.0%
	2009		125	75	51	35	30	316
		%	39.6%	23.7%	16.1%	11.1%	9.5%	100.0%
	Total		1704	962	656	478	349	4149
		%	41.1%	23.2%	15.8%	11.5%	8.4%	100.0%

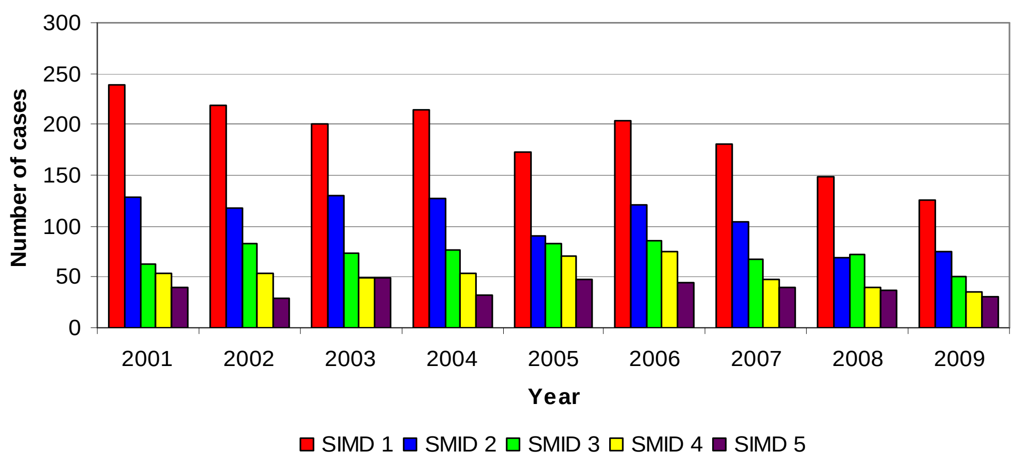


Figure 3. 11 Number of facial injuries - Interpersonal violence related; trends over time by SIMD

3.5.1.3.2 Traffic related (Motor vehicle incident)

The data shows that 6726 patients (14.8%) had suffered a facial injury attributable to transport accidents (Table 3. 16 and Figure 3. 12). Of those, 4552 (67.68%) were males and 2174 (32.32%) were females (M: F = 2.1: 1) (Table 3. 17 and Figure 3. 13). This Male: Female rate ratio is approximately the same for the sample as a whole. However, the number of cases of facial injury due to motor vehicle incident had declined over the study period especially among males in the last four years (Figure 3. 13).

Table 3. 16 Trends of facial injuries- traffic related

Motor vehicle incident	Frequency	%
No	38662	85.2
Yes	6726	14.8
Total	45388	100.0

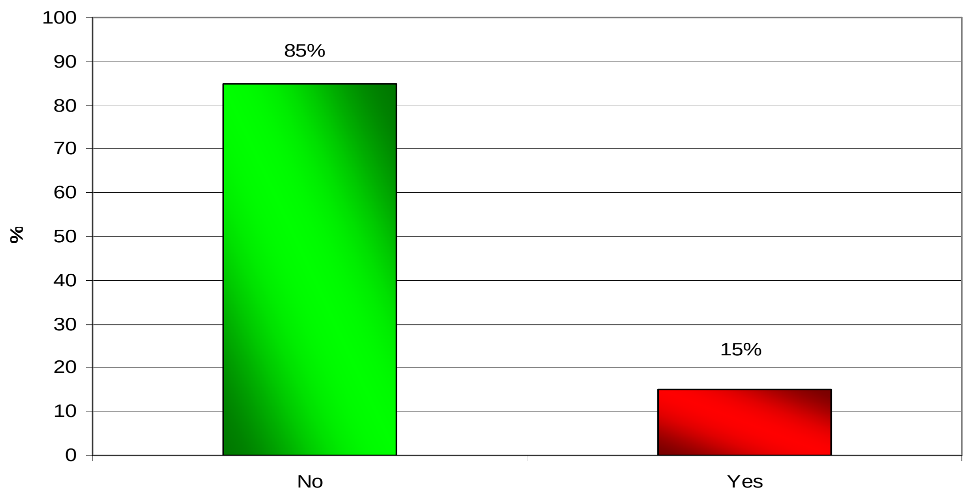


Figure 3. 12 Proportion of facial injuries- traffic related

Table 3. 17 Traffic related facial injuries- trends over time by gender

Traffic injury	Date of injury	Patient Gender		Total
		Male	Female	
Yes	2001	632	301	933
	2002	591	288	879
	2003	633	270	903
	2004	554	258	812
	2005	541	261	802
	2006	478	231	709
	2007	412	203	615
	2008	361	182	543
	2009	350	180	530
Total		4552	2174	6726

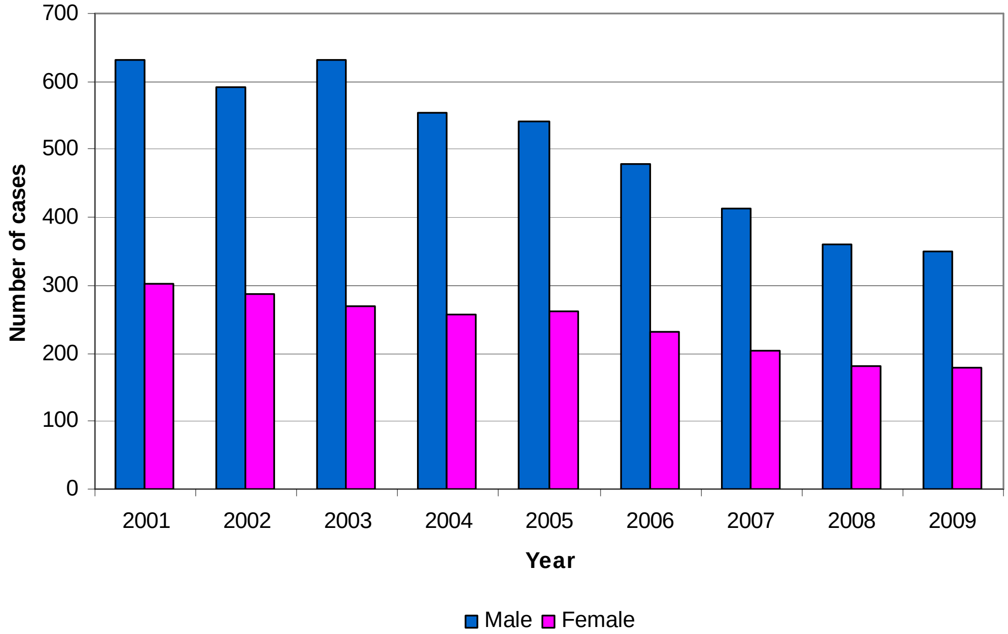


Figure 3. 13 Traffic related facial injuries- trends over time by gender

In general, the proportion of facial injuries caused by motor vehicle incident remained almost the same during the study period with some decline in the proportion in the last four years (Table 3. 18 and Figure 3. 14). However, the data did not show any association between patient's age and facial injury due to motor vehicle incident. The number of cases rose to reach a relative plateau by 4 years of age (Table 3. 19 and Figure 3. 15). This is a different pattern to that revealed when considering the relationship between facial injury and interpersonal violence (Figure 3. 10).

Table 3. 18 Proportion of facial injuries; traffic related- trends over time

	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Cases (*n*)	933	879	903	812	802	709	615	543	530	6726
%	15.60	15.20	16.80	15.80	15.70	14.20	13.30	12.90	12.70	15

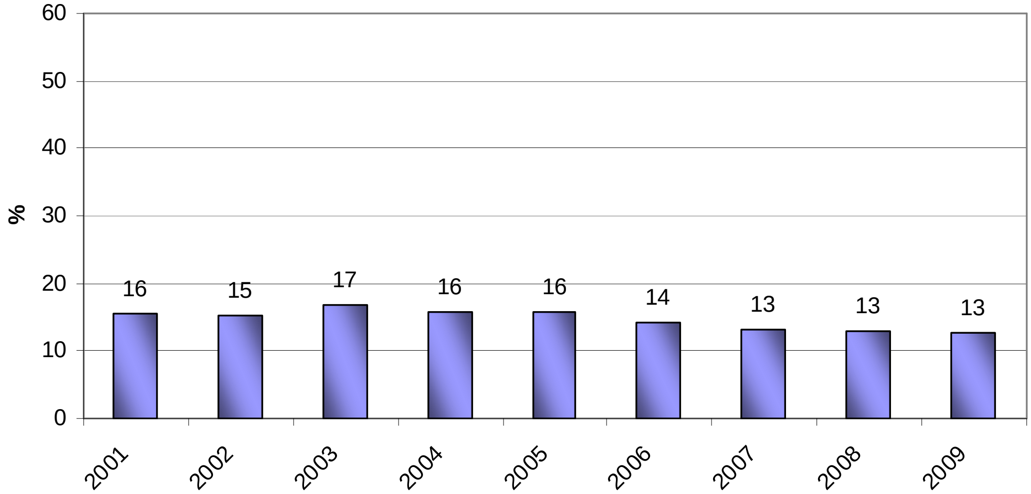


Figure 3. 14 Proportion of facial injuries; traffic related- trends over time

Table 3. 19 Traffic related facial injuries- trends over time by patient's age

Traffic injury	Patient Age	Date of injury									Total
		2001	2002	2003	2004	2005	2006	2007	2008	2009	
Yes	0	9	6	5	4	4	4	3	8	5	48
	1	8	9	12	6	12	12	12	11	9	91
	2	28	22	29	17	12	10	16	18	10	162
	3	30	29	30	26	26	30	24	20	18	233
	4	53	48	47	46	47	36	33	26	22	358
	5	70	52	61	48	49	34	40	33	22	409
	6	63	58	74	56	57	44	36	27	38	453
	7	53	52	65	67	61	45	30	39	36	448
	8	58	55	58	52	55	51	42	31	44	446
	9	50	61	45	50	44	36	40	27	37	390
	10	63	57	66	46	44	43	33	36	28	416
	11	60	69	47	55	45	60	35	28	26	425
	12	76	79	80	75	47	50	58	34	47	546
	13	53	64	64	59	69	54	38	41	44	486
	14	52	55	38	45	61	47	40	35	30	403
	15	73	34	61	50	51	43	32	31	28	403
	16	51	64	52	48	43	49	48	43	34	432
	17	83	65	69	62	75	61	55	55	52	577
	Total	933	879	903	812	802	709	615	543	530	6726

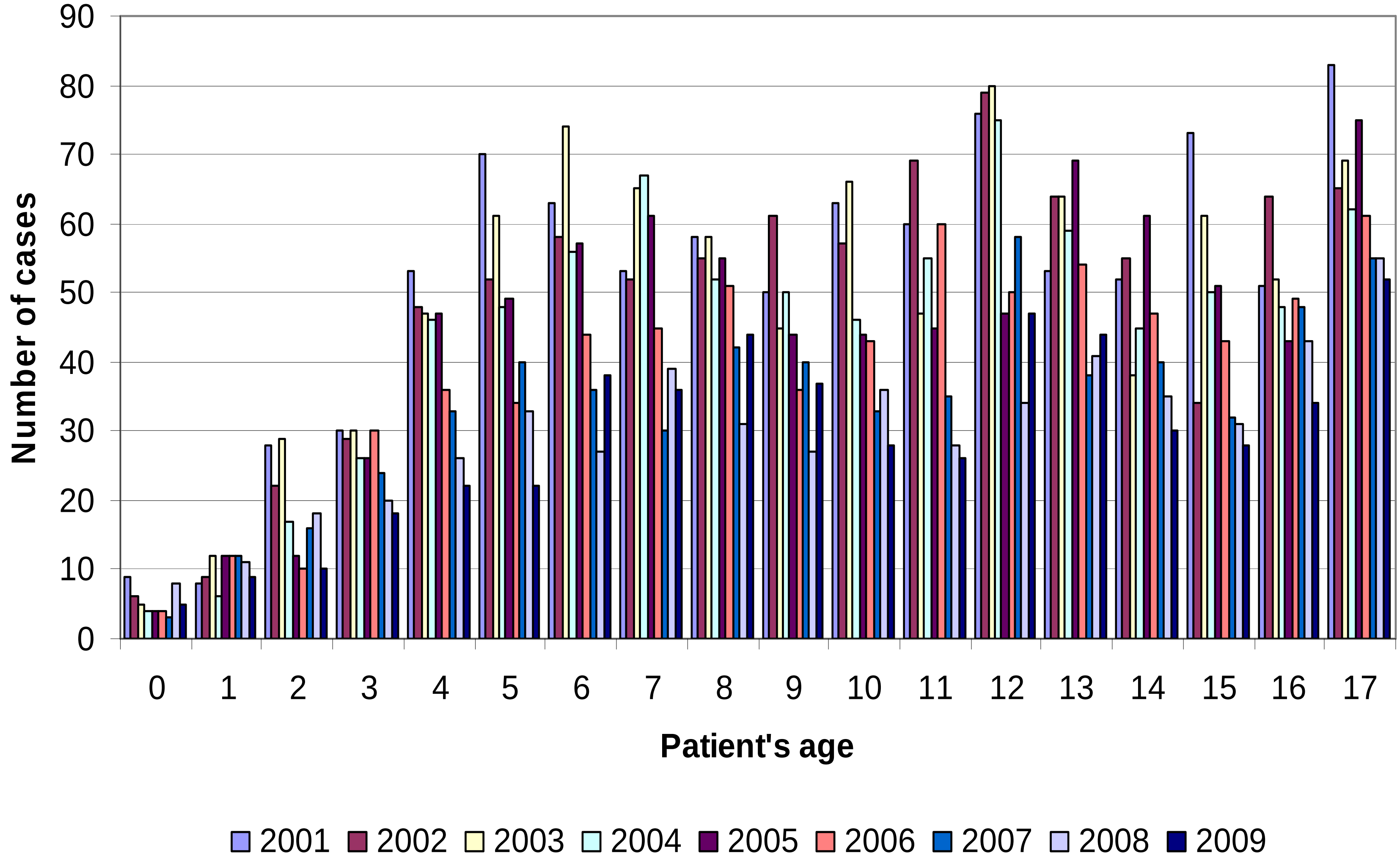


Figure 3. 15 Traffic related facial injury; trends over time with patient's age

Those living in the most deprived areas (SIMD 1 and SIMD 2) consistently sustained more facial injuries as a result of motor vehicle incident. This is represented by the cumulative totals over the study period – 28% SIMD 1 contrasting to 13.9% SIMD 5 (Table 3. 20). This difference between SIMD 1 and 5 is greatest in the first five years of the study period (2001-2005) (Figure 3. 16).

Table 3. 20 Traffic related facial injuries- trends over time by SIMD

MVA	Date of injury		SIMD					Total
			SIMD 1	SIMD 2	SIMD 3	SIMD 4	SIMD 5	
Yes	2001		288	195	194	143	113	933
		%	30.9%	20.9%	20.8%	15.3%	12.1%	100.0%
	2002		246	170	178	157	128	879
		%	28.0%	19.3%	20.3%	17.9%	14.6%	100.0%
	2003		248	211	172	158	114	903
		%	27.5%	23.4%	19.0%	17.5%	12.6%	100.0%
	2004		210	173	180	134	115	812
		%	25.9%	21.3%	22.2%	16.5%	14.2%	100.0%
	2005		261	150	132	135	124	802
		%	32.5%	18.7%	16.5%	16.8%	15.5%	100.0%
	2006		195	159	152	105	98	709
		%	27.5%	22.4%	21.4%	14.8%	13.8%	100.0%
	2007		166	129	123	104	93	615
		%	27.0%	21.0%	20.0%	16.9%	15.1%	100.0%
	2008		135	103	127	101	77	543
		%	24.9%	19.0%	23.4%	18.6%	14.2%	100.0%
	2009		132	97	112	116	73	530
		%	24.9%	18.3%	21.1%	21.9%	13.8%	100.0%
Total			1881	1387	1370	1153	935	6726
		%	28.0%	20.6%	20.4%	17.1%	13.9%	100.0%

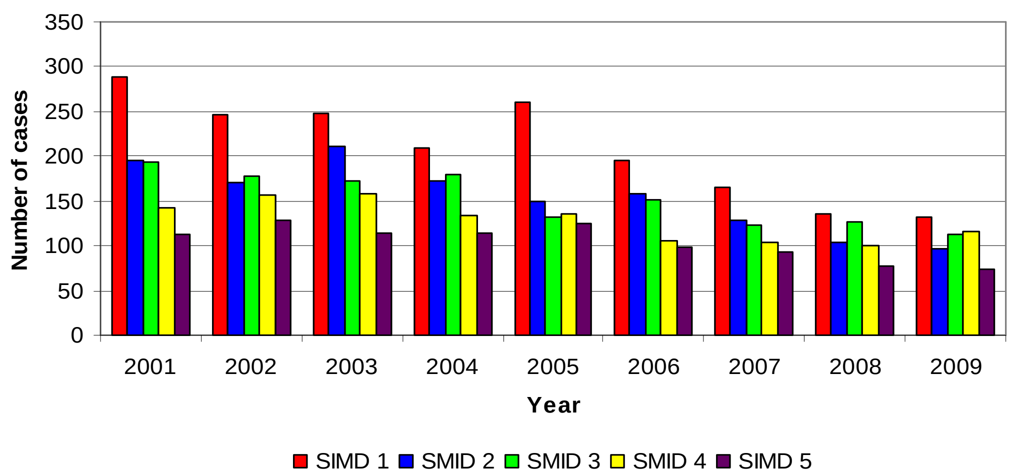


Figure 3. 16 Number of facial injuries - traffic related; trends over time by SIMD

3.5.1.3.3 Non-intentional injuries

The data shows that 27101 patients (59.7%) suffered a facial injury caused by an accident such as a fall (non-intentional) (Table 3. 21 and Figure 3. 17). Sixty three percent (17011) of the cases were males and 37% (10090) were females (M: F = 1.7: 1) (Table 3. 22 and Figure 3. 18). The numbers sustaining facial injury as a result of these accidents stayed almost the same throughout the period of the study for both genders (Figure 3. 18).

Table 3. 21 Trends of facial injuries; non-intentional related

Non-intentional injury	Frequency	%
No	18287	40.3
Yes	27101	59.7
Total	45388	100.0

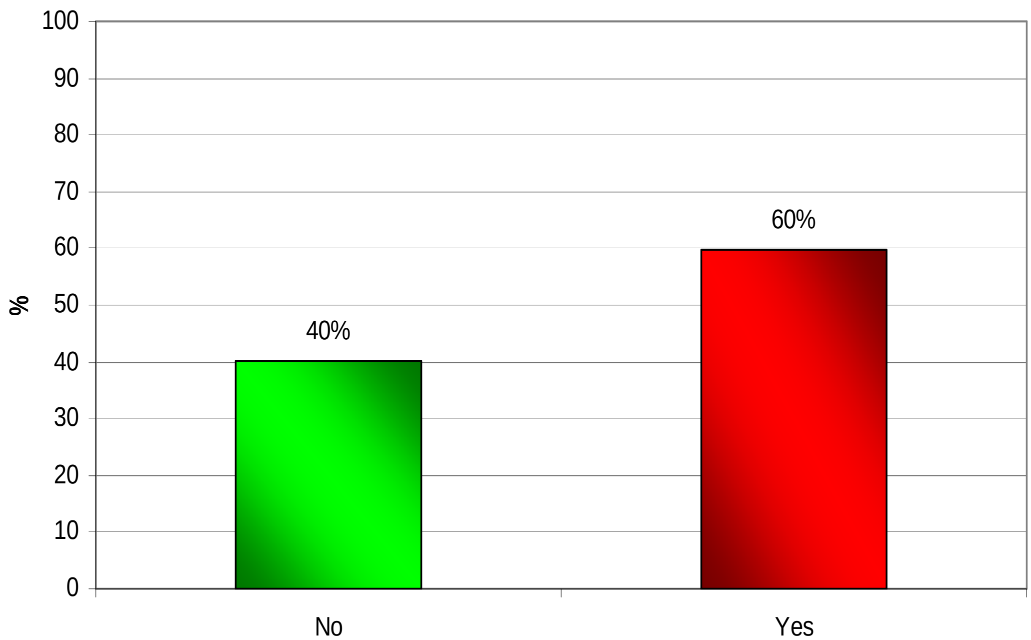


Figure 3. 17 Proportion of facial injury; non-intentional related

Table 3. 22 Non-intentional related facial injury; trends over time by gender

Non-intentional injury	Date of injury	Patient Gender		Total
		Male	Female	
Yes	2001	2302	1323	3625
	%	63.5%	36.5%	100.0%
	2002	2274	1356	3630
	%	62.6%	37.4%	100.0%
	2003	2040	1225	3265
	%	62.5%	37.5%	100.0%
	2004	1945	1122	3067
	%	63.4%	36.6%	100.0%
	2005	1938	1160	3098
	%	62.6%	37.4%	100.0%
	2006	1847	1130	2977
	%	62.0%	38.0%	100.0%
	2007	1695	961	2656
	%	63.8%	36.2%	100.0%
	2008	1484	908	2392
	%	62.0%	38.0%	100.0%
	2009	1486	905	2391
	%	62.1%	37.9%	100.0%
Total		17011	10090	27101
	%	62.8%	37.2%	100.0%

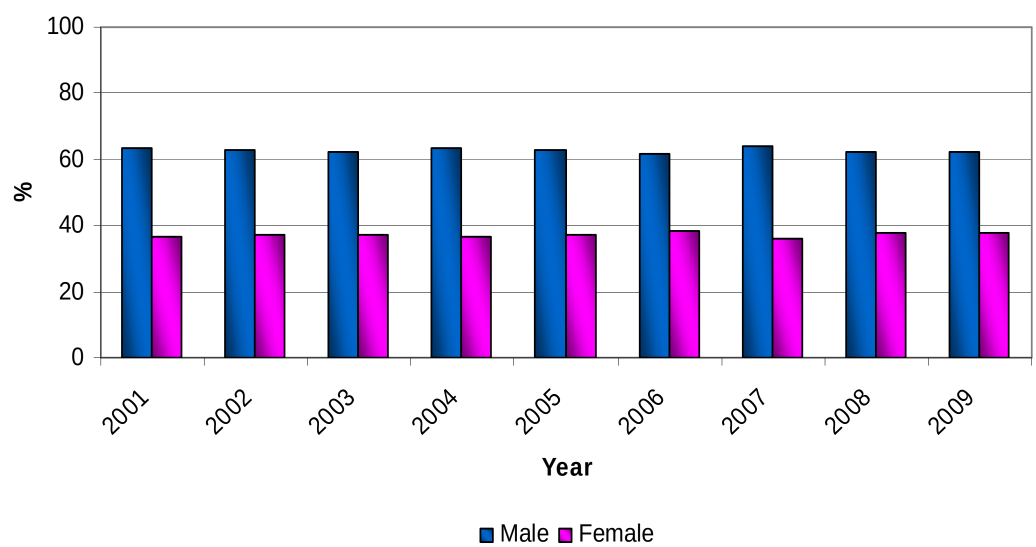


Figure 3. 18 Non-intentional related facial injuries- trends over time by gender

Generally, the proportion of facial injuries with a non-intentional cause remained almost the same during the study period (Table 3.23 and Figure 3. 19). However, the data did show a notable association between younger ages (< 5 years of age) and facial injuries due to accidents such as falls with exposure to mechanical forces. There was then some decline in the number of cases between 5 and 12 years old and a further smaller decline between 12-17 years (and Table 3. 23 and Figure 3. 20).

Table 3.23 Proportion of facial injuries; non-intentional related- trends over time

	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Cases (*n*)	3625	3630	3265	3067	3098	2977	2656	2392	2391	27101
%	60.6	62.6	60.6	59.7	60.8	59.7	57.4	57.0	57.3	59.7

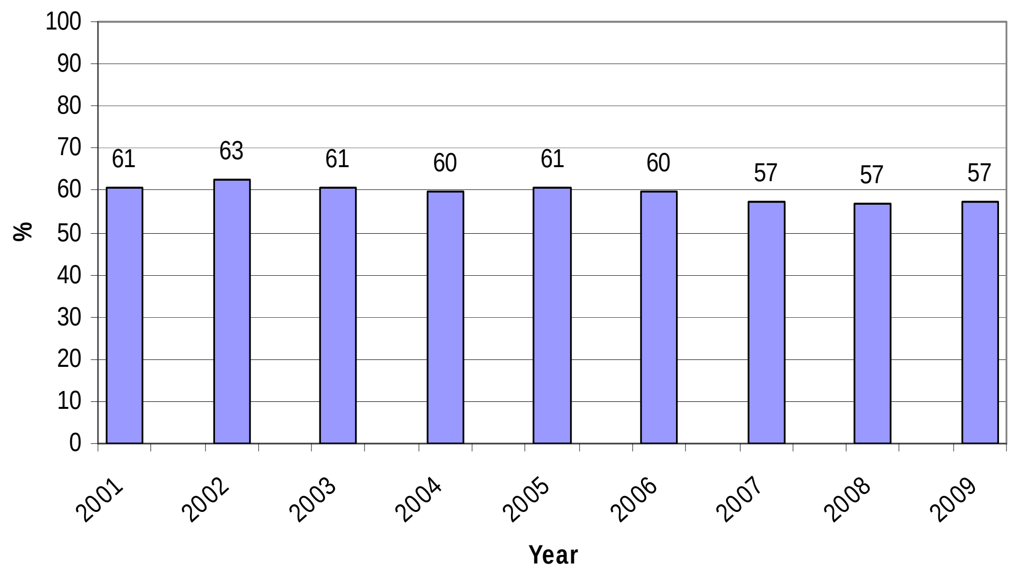


Figure 3. 19 Proportion of facial injuries; non-intentional related- trends over time

Table 3. 24 Non-intentional related facial injuries- trends over time with patient's age

Non-intentional injury	Patient Age	Date of injury									Total
		2001	2002	2003	2004	2005	2006	2007	2008	2009	
Yes	0	315	376	347	374	415	411	294	293	336	3161
	1	421	459	419	425	428	432	373	378	342	3677
	2	338	329	322	273	314	303	297	285	283	2744
	3	257	274	219	210	220	220	195	207	196	1998
	4	247	222	200	179	194	172	153	153	138	1658
	5	219	221	181	171	164	182	128	118	142	1526
	6	196	171	157	156	167	128	117	88	89	1269
	7	161	170	166	151	135	114	117	89	91	1194
	8	167	163	135	128	124	111	112	104	72	1116
	9	170	153	148	137	128	110	113	84	85	1128
	10	185	175	145	129	110	111	113	76	93	1137
	11	172	148	118	144	126	109	104	78	89	1088
	12	186	150	159	152	153	132	97	82	75	1186
	13	154	152	134	117	112	97	110	61	59	996
	14	123	146	93	92	85	83	74	71	78	845
	15	121	109	122	81	81	91	101	90	71	867
	16	96	105	100	81	78	79	74	61	75	749
	17	97	107	100	67	64	92	84	74	77	762
	Total	3625	3630	3265	3067	3098	2977	2656	2392	2391	27101

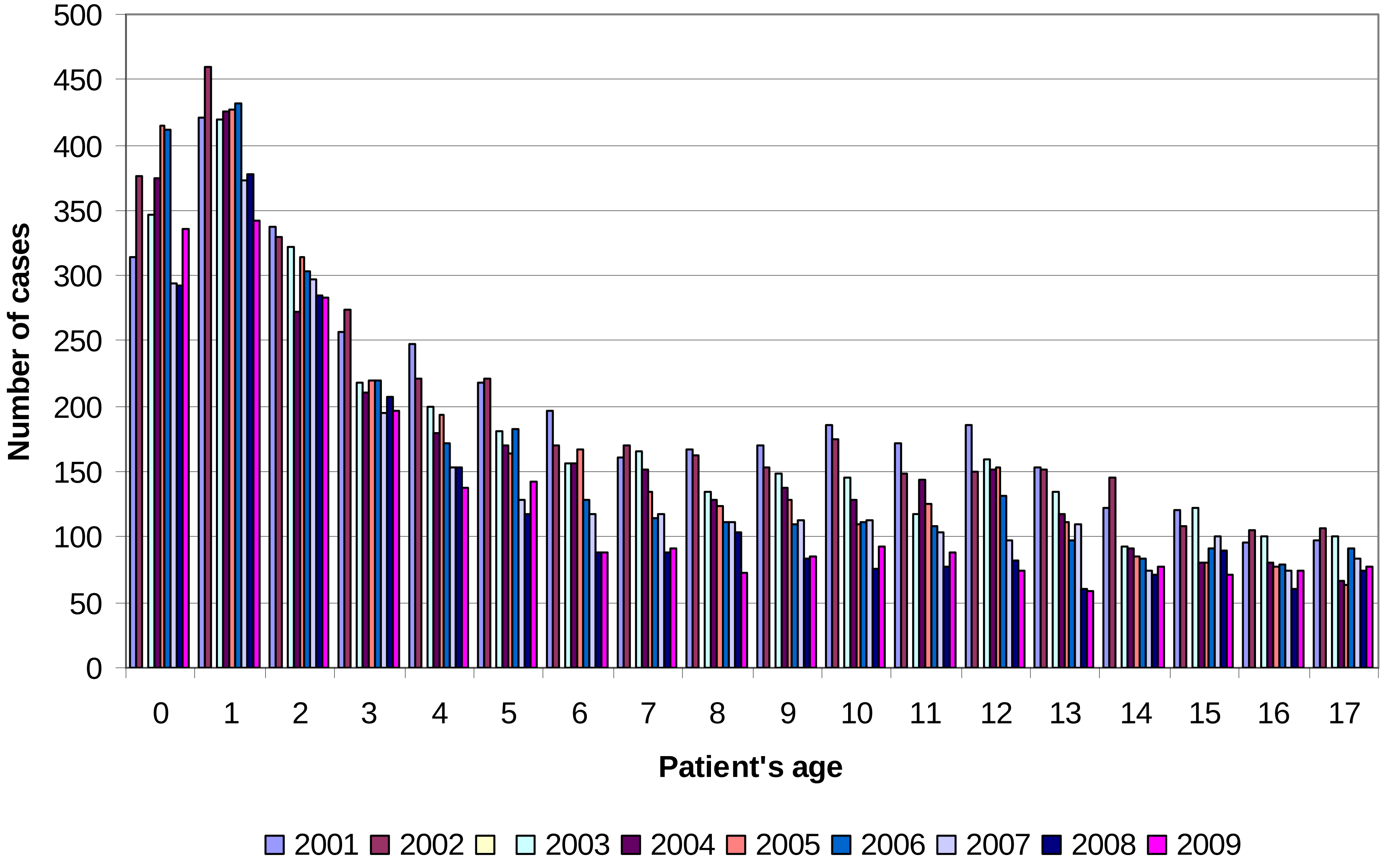


Figure 3. 20 Non-intentional related facial injuries; trends over time with patient's age

There did appear to be a trend between deprivation and non-intentional facial injuries (Table 3.25), with those living in the most deprived areas (SIMD 1) sustaining more injuries than those living in the least deprived areas (Figure 3. 21).

Table 3.25 Non-intentional related facial injury- trends over time by SIMD

Non-intentional injury	Date of injury		SIMD					Total
			SIMD 1	SIMD 2	SIMD 3	SIMD 4	SIMD 5	
Yes	2001		1092	768	598	580	587	3625
		%	30.1%	21.2%	16.5%	16.0%	16.2%	100.0%
	2002		1076	765	627	547	615	3630
		%	29.6%	21.1%	17.3%	15.1%	16.9%	100.0%
	2003		973	670	540	499	583	3265
		%	29.8%	20.5%	16.5%	15.3%	17.9%	100.0%
	2004		855	654	501	508	549	3067
		%	27.9%	21.3%	16.3%	16.6%	17.9%	100.0%
	2005		905	645	526	504	518	3098
		%	29.2%	20.8%	17.0%	16.3%	16.7%	100.0%
	2006		876	599	502	516	484	2977
		%	29.4%	20.1%	16.9%	17.3%	16.3%	100.0%
	2007		722	533	462	473	466	2656
		%	27.2%	20.1%	17.4%	17.8%	17.5%	100.0%
	2008		671	501	417	398	405	2392
		%	28.1%	20.9%	17.4%	16.6%	16.9%	100.0%
	2009		638	513	430	389	421	2391
		%	26.7%	21.5%	18.0%	16.3%	17.6%	100.0%
Total			7808	5648	4603	4414	4628	27101
		%	28.8%	20.8%	17.0%	16.3%	17.1%	100.0%

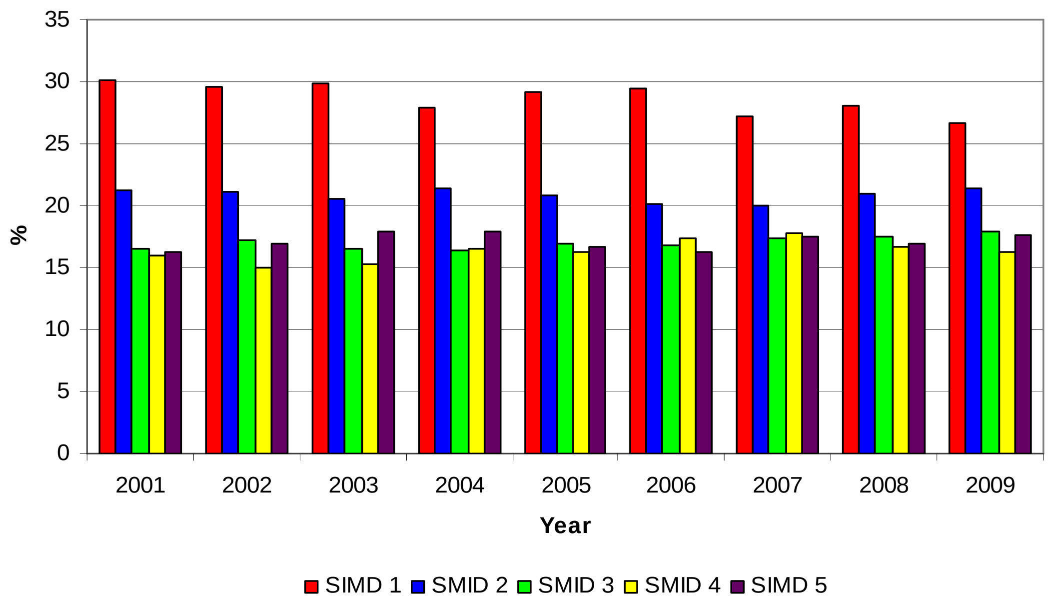


Figure 3. 21 Proportion of non-intentional facial injuries- trends over time by SIMD

3.5.1.3.4 Alcohol-related facial injury

An analysis of alcohol involvement in sustaining facial injuries was completed to determine if any significance could be elicited. The data shows that alcohol was involved in 2058 (4.5%) of facial injuries (Table 3. 26 and Figure 3. 22), among these cases the majority (73.3%) were males and 26.7% were females (M: F = 2.8: 1) (Table 3. 27 and Figure 3. 23).

Table 3. 26 Trends of facial injuries- alcohol related

Alcohol related	Frequency	%
No	43330	95.5
Yes	2058	4.5
Total	45388	100.0

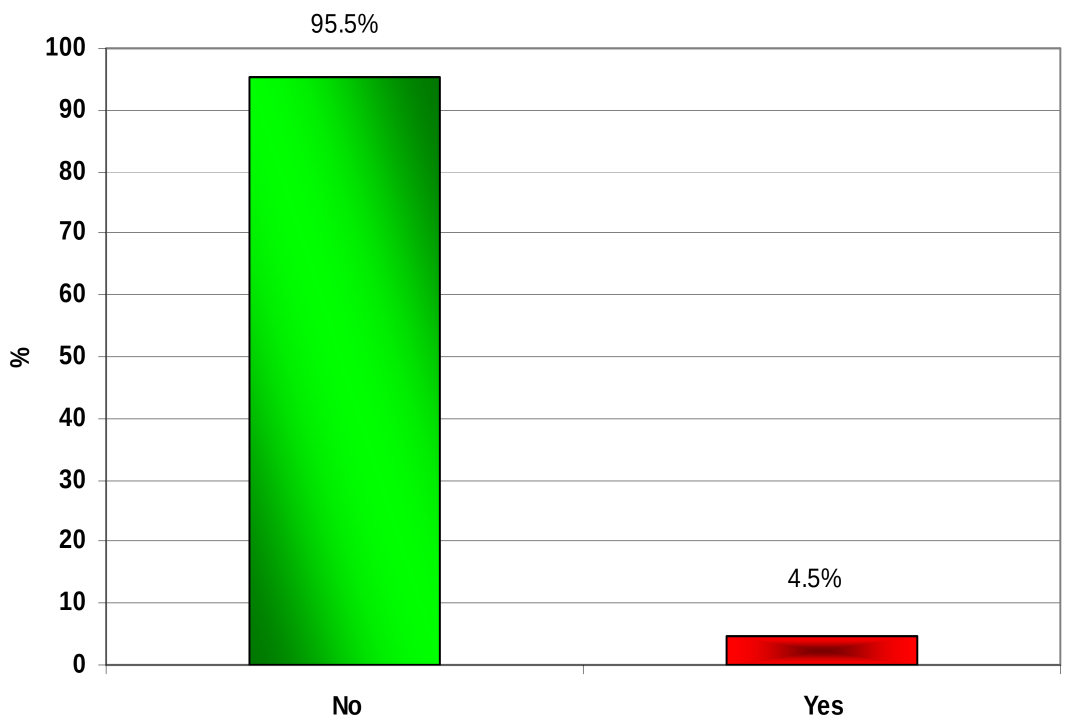


Figure 3. 22 Trends of facial injuries alcohol related

Table 3. 27 Alcohol related facial injury; trends over time by patient's gender

Alcohol related	Date of injury	Patient Gender		Total
		Male	Female	
Yes	2001	176	64	240
	%	73.3%	26.7%	100.0%
	2002	177	74	251
	%	70.5%	29.5%	100.0%
	2003	158	46	204
	%	77.5%	22.5%	100.0%
	2004	166	49	215
	%	77.2%	22.8%	100.0%
	2005	155	45	200
	%	77.5%	22.5%	100.0%
	2006	179	90	269
	%	66.5%	33.5%	100.0%
	2007	208	59	267
	%	77.9%	22.1%	100.0%
	2008	146	55	201
	%	72.6%	27.4%	100.0%
	2009	144	67	211
	%	68.2%	31.8%	100.0%
Total		1509	549	2058
	%	73.3%	26.7%	100.0%

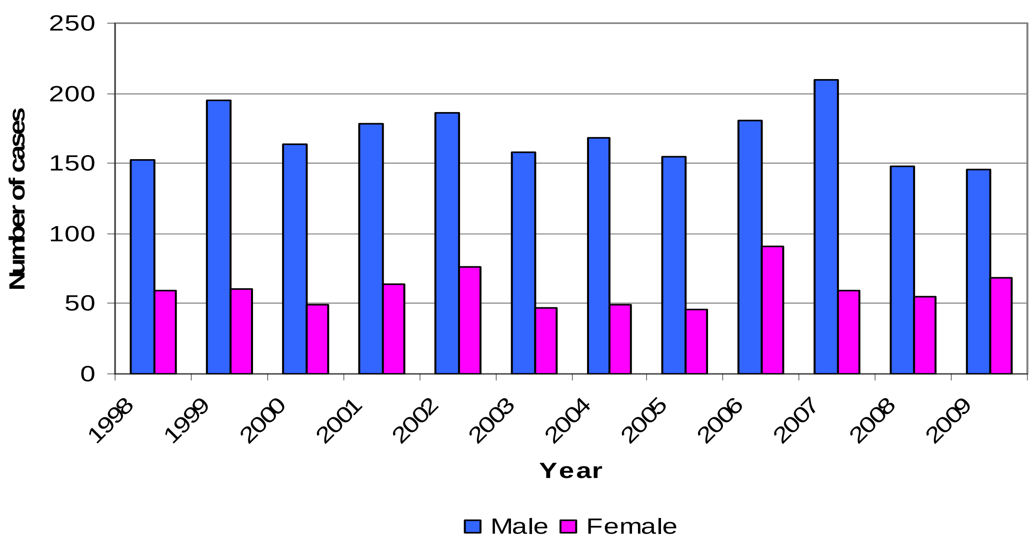


Figure 3. 23 Trends of alcohol related facial injury- trends over time by patient's gender

In general, the numbers of those who sustained alcohol related facial injuries remained almost constant throughout the period of the study for both genders (Figure 3. 23). However notably the overall numbers increased significantly at older ages when alcohol was involved (Table 3. 28 and Figure 3. 24).

Table 3. 28 Alcohol related facial injuries; trends over time by patient's age

Alcohol related	Patient age	Date of injury									Total
		2001	2002	2003	2004	2005	2006	2007	2008	2009	
Yes	0	0	0	1	0	0	0	0	0	0	1
	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	1	0	0	0	0	1
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	1	0	0	0	0	0	0	0	1
	9	1	1	0	1	0	0	0	0	0	3
	10	1	0	0	0	0	1	0	1	1	4
	11	1	0	1	2	2	3	1	0	1	11
	12	12	4	3	5	3	6	10	3	3	49
	13	19	17	17	15	14	17	18	10	7	134
	14	25	50	16	31	21	41	23	16	28	251
	15	52	47	40	40	46	53	60	40	36	414
	16	58	58	56	63	56	67	72	48	67	545
	17	71	73	70	58	57	81	83	83	68	644
	Total	240	251	204	215	200	269	267	201	211	2058

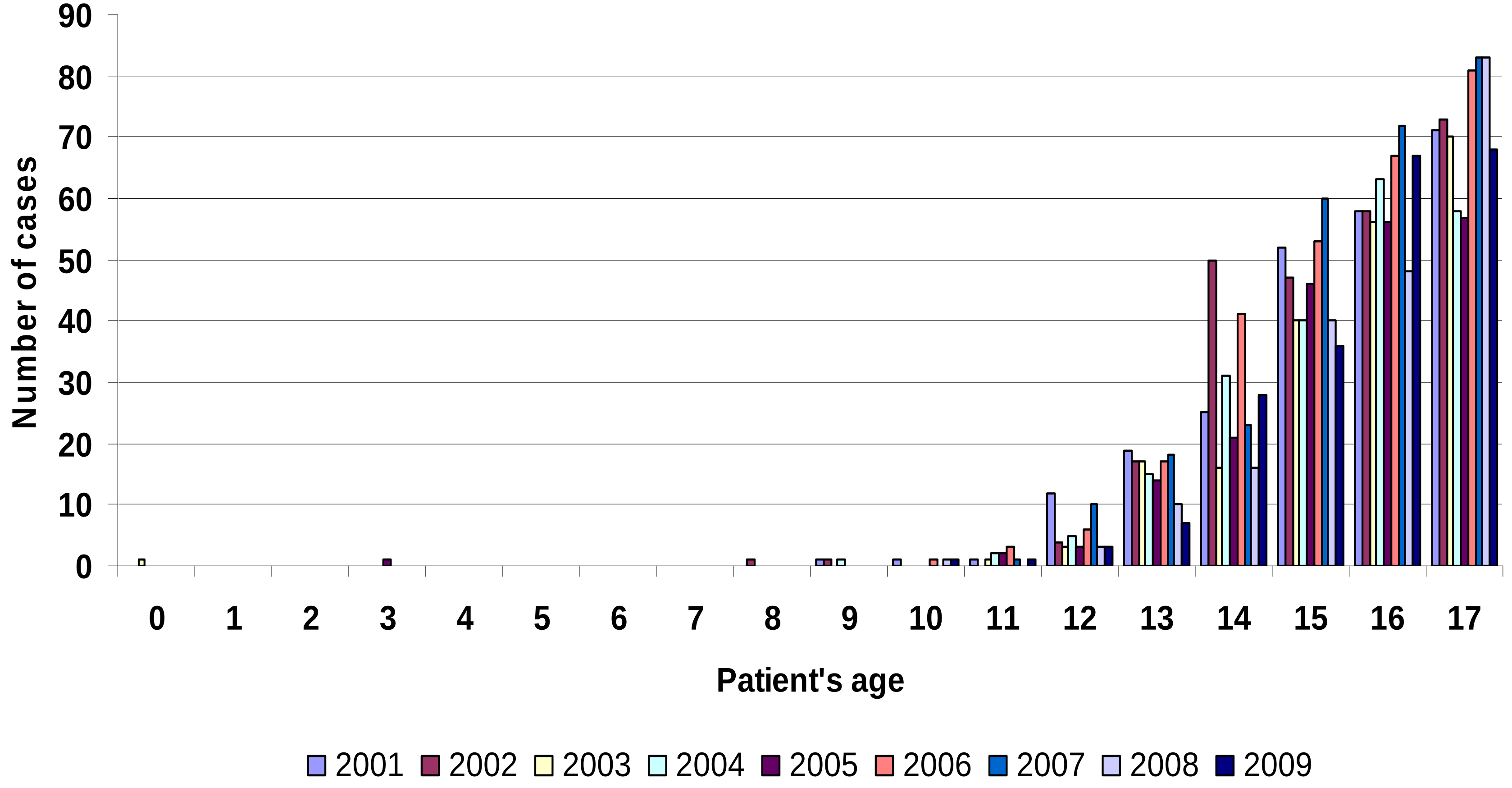


Figure 3. 24 Alcohol related facial injuries; trends over time by patient's age

In general the number of cases where alcohol was involved appeared constant throughout the study period (2001-2009) for all SIMD categories with a smaller number of cases reported in those living in the least deprived areas (Table 3. 29 and Figure 3. 25).

Table 3. 29 Alcohol related facial injury; trends over time by SIMD

Alcohol related	Date of injury		SIMD					Total
			SIMD 1	SIMD 2	SIMD 3	SIMD 4	SIMD 5	
Yes	2001		98	61	27	33	21	240
		%	40.8%	25.4%	11.3%	13.8%	8.8%	100.0%
	2002		101	62	38	37	13	251
		%	40.2%	24.7%	15.1%	14.7%	5.2%	100.0%
	2003		66	53	37	23	25	204
		%	32.4%	26.0%	18.1%	11.3%	12.3%	100.0%
	2004		89	54	36	23	13	215
		%	41.4%	25.1%	16.7%	10.7%	6.0%	100.0%
	2005		75	42	36	27	20	200
		%	37.5%	21.0%	18.0%	13.5%	10.0%	100.0%
	2006		103	59	47	42	18	269
		%	38.3%	21.9%	17.5%	15.6%	6.7%	100.0%
	2007		107	54	54	29	23	267
		%	40.1%	20.2%	20.2%	10.9%	8.6%	100.0%
	2008		81	49	39	18	14	201
		%	40.3%	24.4%	19.4%	9.0%	7.0%	100.0%
	2009		85	49	35	30	12	211
		%	40.3%	23.2%	16.6%	14.2%	5.7%	100.0%
Total			805	483	349	262	159	2058
		%	39.1%	23.5%	17.0%	12.7%	7.7%	100.0%

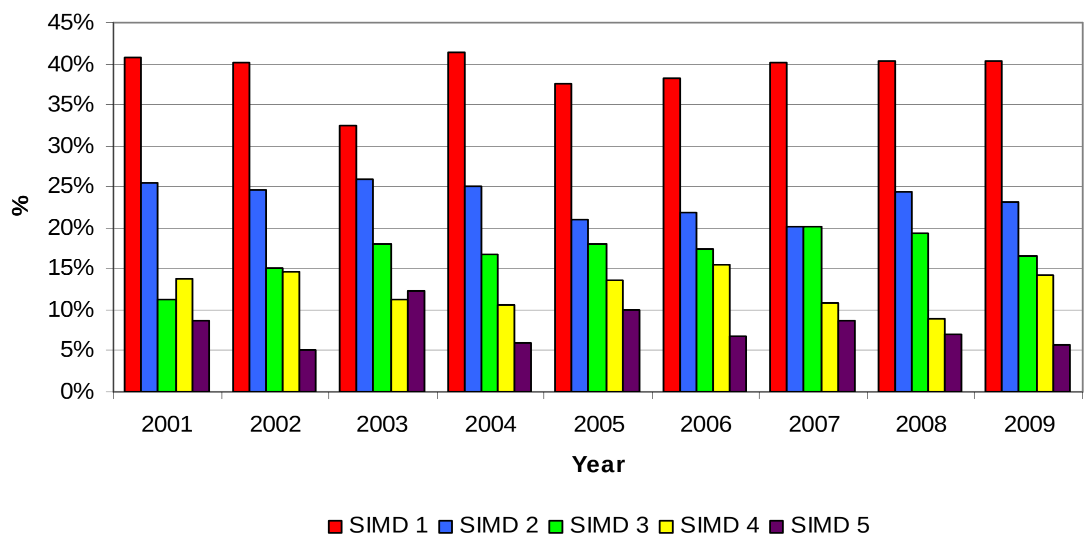


Figure 3. 25 Proportion of alcohol related facial injuries- trends over time by SIMD

Table 3. 30 Analyzes alcohol involvement with regard to the mechanism of injury. It is obvious that alcohol was mostly involved in those injuries resulting from interpersonal violence (Figure 3. 1).

Table 3. 30 Analysis of alcohol involvement by mechanism of injury

Alcohol related		Interpersonal violence		Total
		No	Yes	
No		39807	3523	43330
	%	97%	85%	95.5%
Yes		1432	626	2058
	%	3%	15%	4.5%
Total		41239	4149	45388
	%	100%	100%	100%
		Motor vehicle incident		
No		36736	6594	43330
	%	95%	98%	95.5
Yes		1926	132	2058
	%	5%	2%	4.5
Total		38662	6726	45388
	%	100	100	100
		Non-intentional causes		
No		17162	26168	43330
	%	94%	97%	95.5%
Yes		1125	933	2058
	%	6%	3%	4.5%
Total		18287	27101	45388
	%	100.0%	100.0%	100.0%

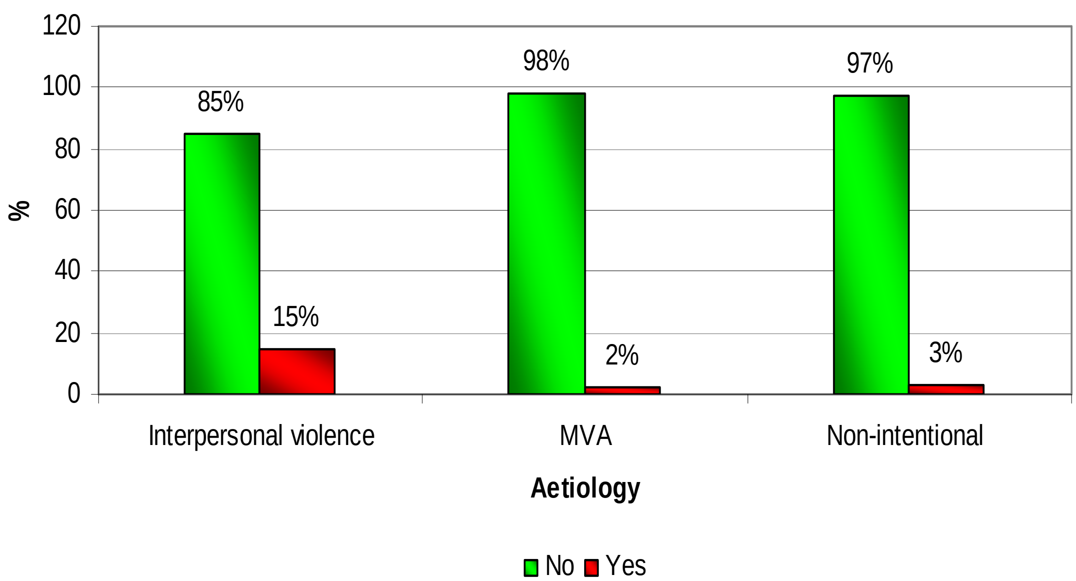


Figure 3. 26 Analysis of alcohol involvement by mechanism of injury

The aetiological mechanisms of facial injuries in each Health Board were investigated to determine the main cause in each different Health Board. Non-intentional injuries were the predominant injuries in all of Health Boards as shown in (Figure 3. 27).

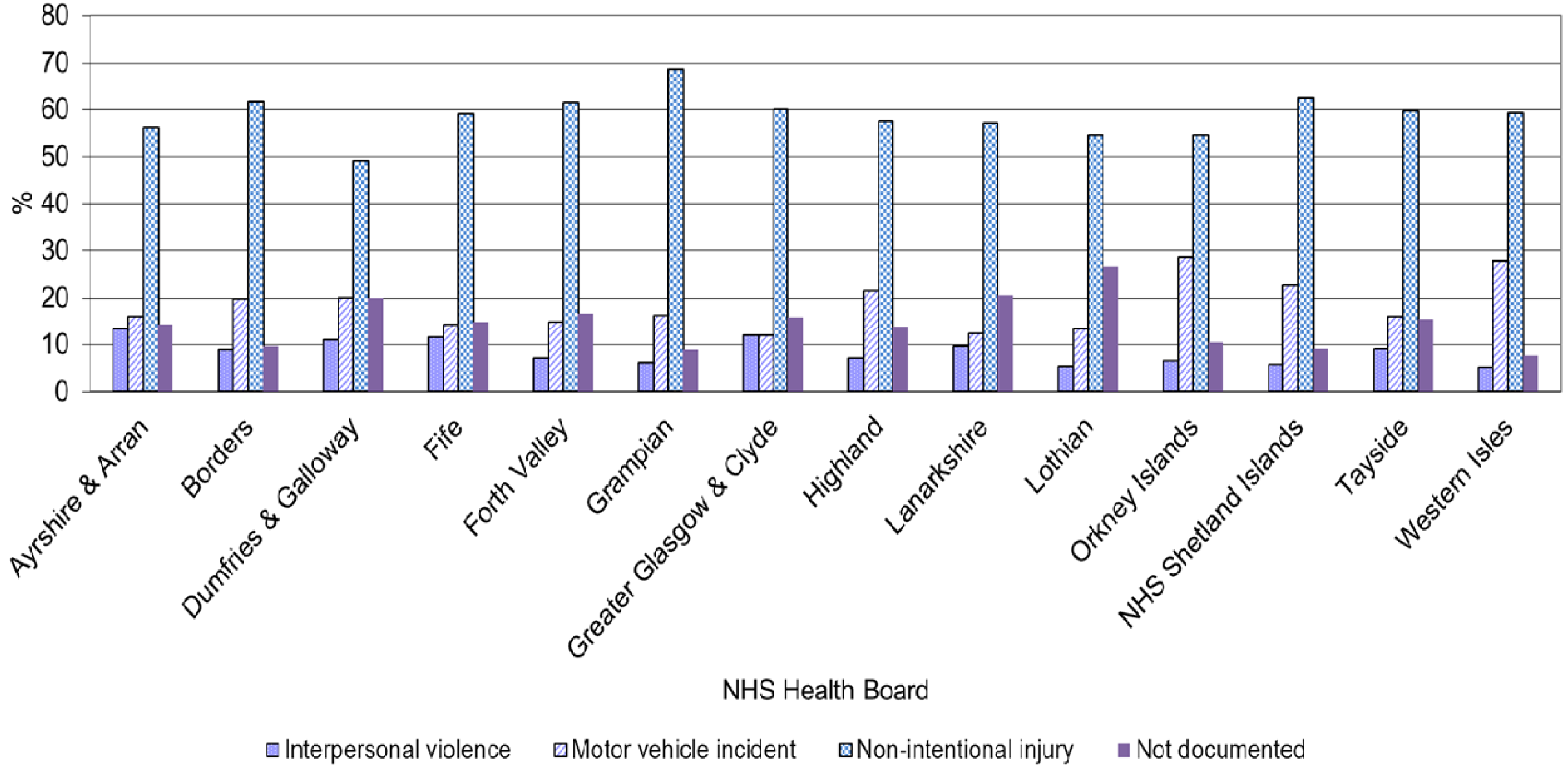


Figure 3. 27 Aetiological mechanism of facial injury across Scottish Health Boards

3.5.2 A univariate analysis of study variables

3.5.2.1 Age univariate results

The 'Criteria for Assessing Goodness of Fit' section of the Poisson regression output (Figure 3. 28) suggests that, because ratios 'Value/DF' for both deviance and Pearson Chi-Square statistics are close to 1, to conclude that the fit of the Poisson model is quite adequate to describe the counts of facial injury among different ages.

The GENMOD Procedure

Model Information

Data Set	WORK.TRAUMA
Distribution	Poisson
Link Function	Log
Dependent Variable	EVENTS
Offset Variable	LOG_POP

Number of Observations Read	21060
Number of Observations Used	21060

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	21E3	33296.4514	1.5824
Scaled Deviance	21E3	33296.4514	1.5824
Pearson Chi-Square	21E3	34308.2436	1.6305
Scaled Pearson X2	21E3	34308.2436	1.6305
Log Likelihood		9597.7190	

Algorithm converged

.

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
AGE	17	3675.29	<.0001

Figure 3. 28 Output from Poisson regression (Age univariate analysis)

Facial injury, based on this study showed peaks of incidence at the extremes of age. Those aged < 3 years of age and those at 15 - 17 years were at greatest risk of sustaining facial injury ($p < 0.001$) as shown in Table 3. 32 and Figure 3. 29.

Table 3. 31 Relative risk of sustaining a facial injury according to age

VAR	CHISQ_TYPE3	PVAL_TYPE3	LEVEL	RR	RR_L	RR_U	P
AGE	3675.29	<.001	1	1.17	1.12	1.23	<.001
	.	.	2	0.92	0.88	0.97	<.001
	.	.	3	0.71	0.67	0.74	<.001
	.	.	4	0.64	0.60	0.67	<.001
	.	.	5	0.61	0.58	0.65	<.001
	.	.	6	0.54	0.51	0.57	<.001
	.	.	7	0.51	0.48	0.54	<.001
	.	.	8	0.47	0.45	0.50	<.001
	.	.	9	0.46	0.43	0.48	<.001
	.	.	10	0.47	0.44	0.49	<.001
	.	.	11	0.46	0.44	0.49	<.001
	.	.	12	0.55	0.52	0.58	<.001
	.	.	13	0.55	0.52	0.58	<.001
	.	.	14	0.59	0.56	0.62	<.001
	.	.	15	0.68	0.65	0.71	<.001
	.	.	16	0.74	0.70	0.78	<.001
	.	.	17	0.84	0.80	0.88	<.001

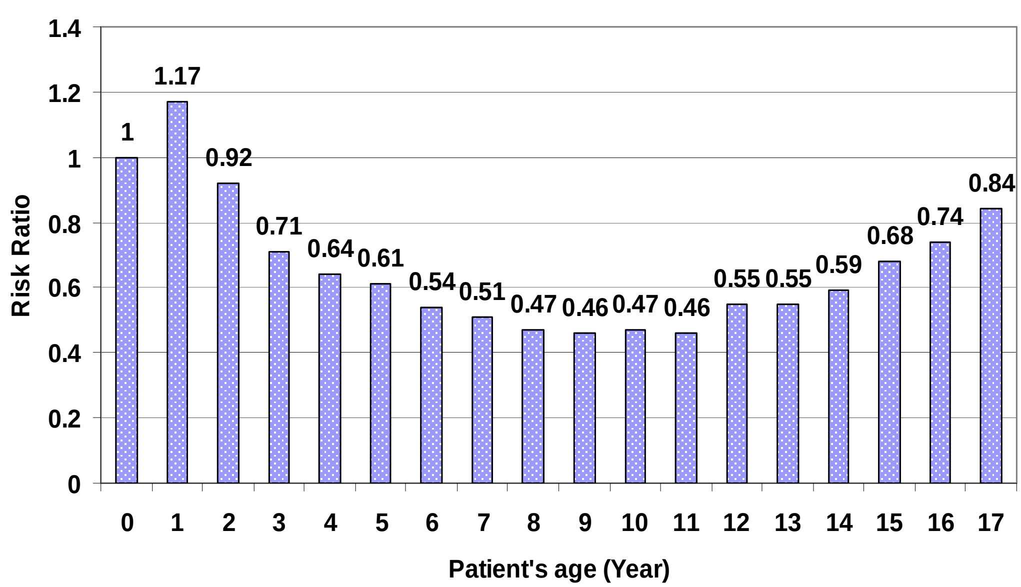


Figure 3. 29 Relative risk of sustaining a facial injury according to age

3.5.2.2 Gender univariate results

According to this study, the 'Criteria for Assessing Goodness of Fit' section of the Poisson regression output (Figure 3. 30) suggests that, because ratios 'Value/DF' for both deviance and Pearson Chi-Square statistics are close to 1, to conclude that the fit of the Poisson model is quite adequate to describe the counts of facial injury among different genders.

The GENMOD Procedure

Model Information

Data Set	WORK.TRAUMA
Distribution	Poisson
Link Function	Log
Dependent Variable	EVENTS
Offset Variable	LOG_POP

Number of Observations Read	21060
Number of Observations Used	21060

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	21E3	32305.6633	1.5341
Scaled Deviance	21E3	32305.6633	1.5341
Pearson Chi-Square	21E3	35447.0558	1.6833
Scaled Pearson X2	21E3	35447.0558	1.6833
Log Likelihood		10093.1131	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
GENDER	1	4666.07	<.0001

Figure 3. 30 Output from Poisson regression (Gender univariate analysis)

Gender was associated with an increased risk of facial injury. Males were affected more than females with the relative risk (RR) for males being 1.94 times greater than for females ($p < 0.001$) as shown in Table 3. 32 and Figure 3. 31.

Table 3. 32 Relative risk of sustaining a facial injury according to gender

VAR	CHISQ_TYPE3	PVAL_TYPE3	LEVEL	RR	RR_L	RR_U	P
GENDER	4666.07	<.001	Male	1.94	1.90	1.98	<.001

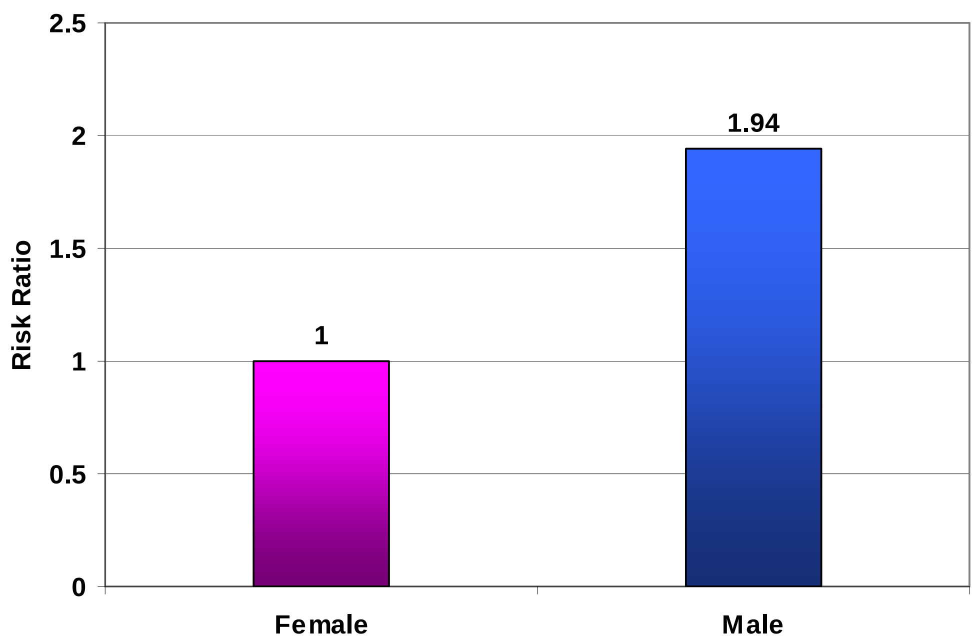


Figure 3. 31 Relative risk of sustaining a facial injury according to gender

3.5.2.3 SIMD univariate results

The ‘Criteria for Assessing Goodness of Fit’ section of the Poisson regression output (Figure 3. 32) suggests that, because ratios ‘Value/DF’ for both deviance and Pearson Chi-Square statistics are close to 1, to conclude that the fit of the Poisson model is quite adequate to describe the counts of facial injury among different SIMD categories.

The GENMOD Procedure

Model Information

Data Set	WORK.TRAUMA
Distribution	Poisson
Link Function	Log
Dependent Variable	EVENTS
Offset Variable	LOG_POP

Number of Observations Read	21060
Number of Observations Used	21060

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	21E3	35095.6409	1.6669
Scaled Deviance	21E3	35095.6409	1.6669
Pearson Chi-Square	21E3	37170.5232	1.7654
Scaled Pearson X2	21E3	37170.5232	1.7654
Log Likelihood		8698.1243	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
SIMD	4	1876.10	<.0001

Figure 3. 32 Output from Poisson regression (SIMD univariate analysis)

There was a significant association between the relative risk of facial injury and deprivation; an increase in the relative risk of facial injury being associated with increasing social deprivation (p<0.001). SIMD 1 (most deprived) had the highest relative risk of 1.70 as shown in Table 3. 33 and Figure 3. 33.

Table 3. 33 Relative risk of sustaining a facial injury according to SIMD

VAR	CHISQ_TYPE3	PVAL_TYPE3	LEVEL	RR	RR_L	RR_U	P
SIMD	1876.10	<.001	1	1.70	1.65	1.75	<.001
	.	.	2	1.38	1.34	1.42	<.001
	.	.	3	1.16	1.12	1.20	<.001
	.	.	4	1.05	1.02	1.09	0.002

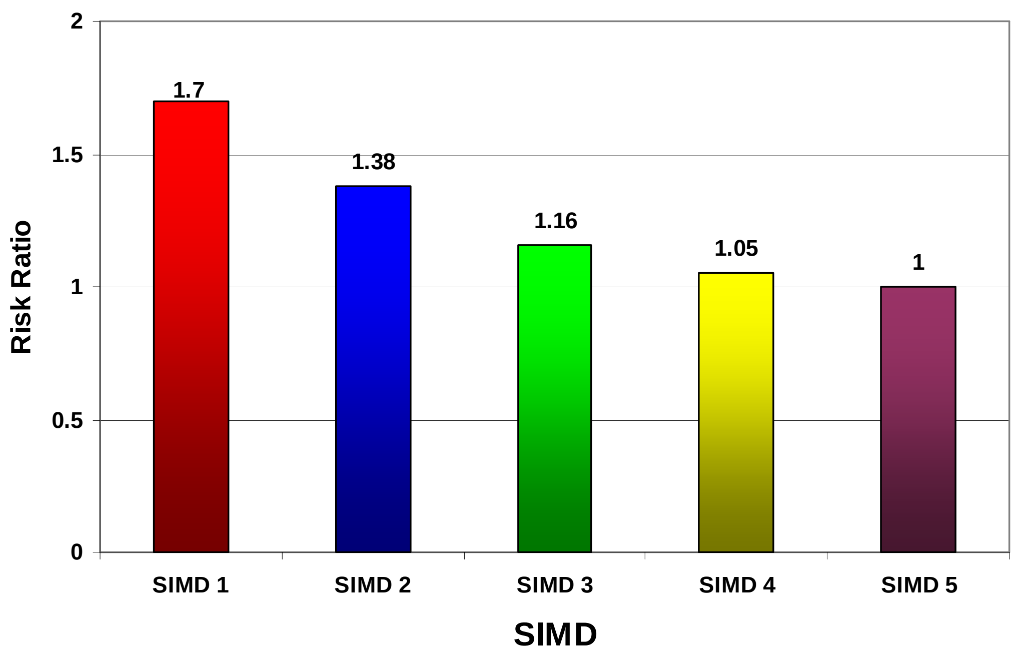


Figure 3. 33 Relative risk of sustaining a facial injury according to SIMD

3.5.2.4 Health Board (area) univariate results

The 'Criteria for Assessing Goodness of Fit' section of the Poisson regression output (Figure 3. 34) suggests that, because ratios 'Value/DF' for both deviance and Pearson Chi-Square statistics are close to 1, to conclude that the fit of the Poisson model is quite adequate to describe the counts of facial injury in different NHS Health Boards.

The GENMOD Procedure

Model Information

Data Set	WORK.TRAUMA
Distribution	Poisson
Link Function	Log
Dependent Variable	EVENTS
Offset Variable	LOG_POP

Number of Observations Read	21060
Number of Observations Used	21060

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	21E3	35410.4703	1.6825
Scaled Deviance	21E3	35410.4703	1.6825
Pearson Chi-Square	21E3	37067.8727	1.7613
Scaled Pearson X2	21E3	37067.8727	1.7613
Log Likelihood		8540.7095	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
HB	13	1561.27	<.0001

Figure 3. 34 Output from Poisson regression (Health Board univariate analysis)

The relative risk of facial injury varied significantly between individual Health Boards (areas). The highest rate was reported in Grampian NHS Health Board of 1.63 ($p < 0.001$) as shown in Table 3. 34 and Figure 3. 35.

Table 3. 34 Relative risk of sustaining a facial injury according to Health Board

VAR	CHISQ_TYPE3	PVAL_TYPE3	LEVEL	RR	RR_L	RR_U	P
HB	1561.27	<.001	Ayrshire	1.22	1.17	1.27	<.001
	.	.	Borders	1.23	1.16	1.31	<.001
	.	.	Dumfries	0.69	0.64	0.74	<.001
	.	.	Fife	1.10	1.05	1.14	<.001
	.	.	Forth	1.02	0.97	1.07	0.387
	.	.	Glasgow	1.07	1.03	1.10	<.001
	.	.	Grampian	1.63	1.57	1.68	<.001
	.	.	Highland	0.94	0.90	0.99	0.018
	.	.	Lanark	0.94	0.91	0.98	0.002
	.	.	Orkney	0.91	0.77	1.07	0.242
	.	.	Shetland	1.00	0.87	1.15	0.989
	.	.	Tayside	0.92	0.88	0.96	<.001
	.	.	Western	1.08	0.95	1.23	0.244

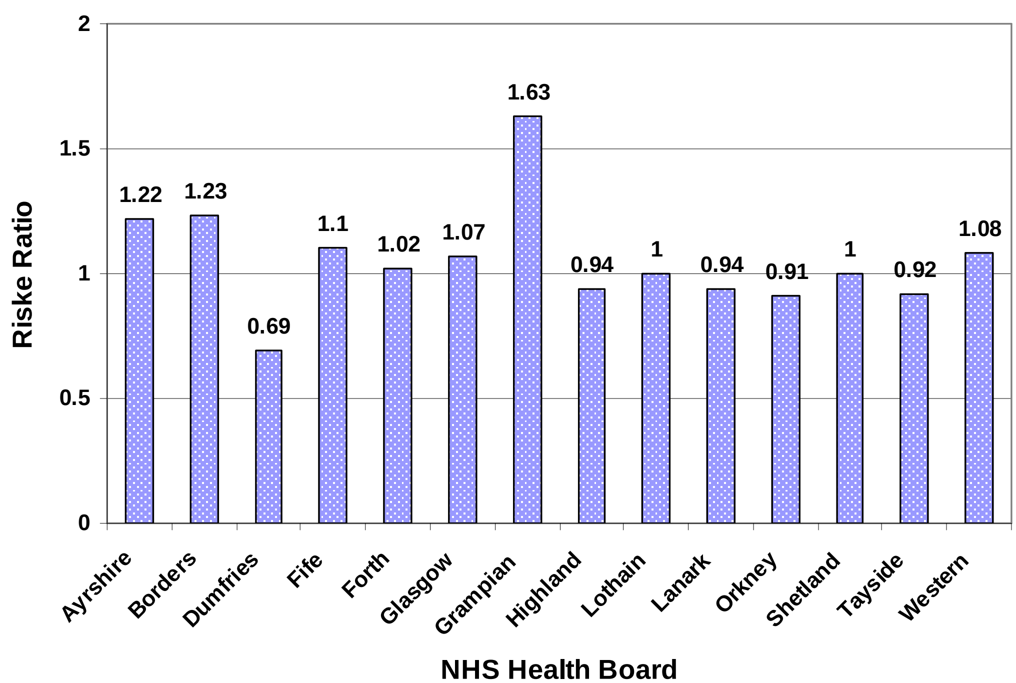


Figure 3. 35 Relative risk of sustaining a facial injury according to Health Board

3.5.3 A multivariate analysis of study variables

The 'Criteria for Assessing Goodness of Fit' section of the Multivariate Poisson regression output (Figure 3. 36) suggests that, because ratios 'Value/DF' for both deviance and Pearson Chi-Square statistics are close to 1, to conclude that the fit of the Poisson model is quite adequate to describe the counts of facial injury among study variables.

The GENMOD Procedure

Model Information

Data Set	WORK.TRAUMA
Distribution	Poisson
Link Function	Log
Dependent Variable	EVENTS
Offset Variable	LOG_POP

Number of Observations Read	21060
Number of Observations Used	21060

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	21E3	24103.6570	1.1469
Scaled Deviance	21E3	24103.6570	1.1469
Pearson Chi-Square	21E3	24024.7172	1.1432
Scaled Pearson X2	21E3	24024.7172	1.1432
Log Likelihood		14194.1162	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
YEAR	8	551.05	<.0001
HB	13	2225.74	<.0001
SIMD	4	2403.55	<.0001
GENDER	1	4680.07	<.0001
AGE	17	3607.74	<.0001

Figure 3. 36 Output from Poisson regression (multivariate analysis)

Multivariate analysis of study variable was not notably different from univariate analysis (Table 3. 35).

Table 3. 35 Summary of adjusted model of facial injuries by study variables: Year, Health Board, SIMD, Gender and Age

Variable	Level	Events	POP_1000	Rate (per1,000)	Risk ratio (95% CI)**	*p* Value
YEAR	2001	5984	1097.61	5.45	1*	
	2002	5796	1085.80	5.34	0.98 (0.95-1.02)	0.274
	2003	5384	1073.67	5.01	0.92 (0.89-0.96)	<.001
	2004	5137	1066.65	4.82	0.88 (0.85-0.92)	<.001
	2005	5096	1059.03	4.81	0.88 (0.85-0.91)	<.001
	2006	4987	1050.19	4.75	0.86 (0.83-0.90)	<.001
	2007	4631	1047.41	4.42	0.80 (0.77-0.83)	<.001
	2008	4197	1045.69	4.01	0.72 (0.70-0.75)	<.001
	2009	4176	1042.15	4.01	0.72 (0.69-0.75)	<.001
Health Board	Lothain	6261	1432.14	4.37	1*	
	Ayrshire	3710	694.28	5.34	1.08 (1.04-1.13)	<.001
	Borders	1114	205.45	5.42	1.32 (1.24-1.41)	<.001
	Dumfries	814	268.78	3.03	0.68 (0.63-0.73)	<.001
	Fife	3262	679.44	4.80	1.04 (1.00-1.09)	0.055
	Forth	2487	556.34	4.47	1.00 (0.96-1.05)	0.953
	Glasgow	10345	2220.29	4.66	0.93 (0.90-0.96)	<.001
	Grampian	7015	986.66	7.11	1.76 (1.71-1.83)	<.001
	Highland	2358	570.11	4.14	0.95 (0.90-0.99)	0.028
	Lanark	4556	1107.65	4.11	0.85 (0.82-0.88)	<.001
	Orkney	154	37.50	4.11	1.00 (0.85-1.17)	0.966
	Shetland	207	46.15	4.48	1.07 (0.93-1.22)	0.367
	Tayside	2872	714.69	4.02	0.90 (0.86-0.94)	<.001
	Western	233	48.72	4.78	1.01 (0.88-1.15)	0.939
SIMD	5 (Least deprived)	7156	1916.27	3.73	1*	
	4	7233	1837.34	3.94	1.08 (1.04-1.11)	<.001
	3	7890	1818.40	4.34	1.22 (1.18-1.26)	<.001
	2	9589	1863.09	5.15	1.50 (1.45-1.55)	<.001
	1(Most deprived)	13520	2133.09	6.34	1.89 (1.83-1.95)	<.001
Gender	Female	14954	4668.37	3.20	1*	
	Male	30434	4899.82	6.21	1.94 (1.90-1.98)	<.001
AGE	0	3568	494.30	7.22	1*	
	1	4144	490.07	8.46	1.18 (1.12-1.23)	<.001
	2	3241	487.53	6.65	0.93 (0.88-0.97)	0.001
	3	2489	488.27	5.10	0.71 (0.68-0.75)	<.001
	4	2261	492.32	4.59	0.64 (0.61-0.68)	<.001
	5	2200	495.88	4.44	0.62 (0.59-0.65)	<.001
	6	1955	501.53	3.90	0.54 (0.52-0.58)	<.001
	7	1870	510.55	3.66	0.51 (0.48-0.54)	<.001
	8	1778	521.77	3.41	0.48 (0.45-0.50)	<.001
	9	1766	534.24	3.31	0.46 (0.44-0.49)	<.001
	10	1835	546.31	3.36	0.47 (0.45-0.50)	<.001
	11	1859	554.31	3.35	0.47 (0.44-0.50)	<.001
	12	2233	560.25	3.99	0.56 (0.53-0.59)	<.001
	13	2240	567.15	3.95	0.55 (0.53-0.58)	<.001
	14	2434	573.53	4.24	0.60 (0.57-0.63)	<.001
	15	2845	579.91	4.91	0.69 (0.66-0.72)	<.001
	16	3122	585.12	5.34	0.75 (0.71-0.79)	<.001
	17	3548	585.14	6.06	0.85 (0.81-0.89)	<.001

*Reference. **Rate ratios are fully adjusted by each variable

Multivariate analysis shows that gender was associated with an increased risk of facial injury. Males were affected more than females with the relative risk (RR) for males being 1.94 times greater than for females ($p < 0.001$) (Table 3. 35 and Figure 3. 37).

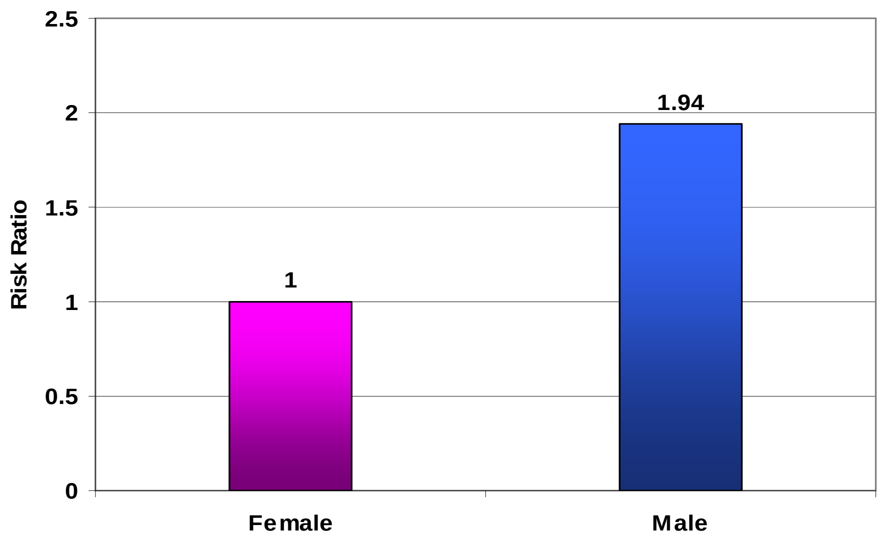


Figure 3. 37 Relative risk of sustaining a facial injury according to gender (Multivariate analysis)

Through multivariate analysis of study variables, facial injury showed peaks of incidence at the extremes of age. Those aged <3 years of age and those at 15 - 17 years were at greatest risk of sustaining facial injury ($p < 0.001$) (Table 3. 35 and Figure 3. 38).

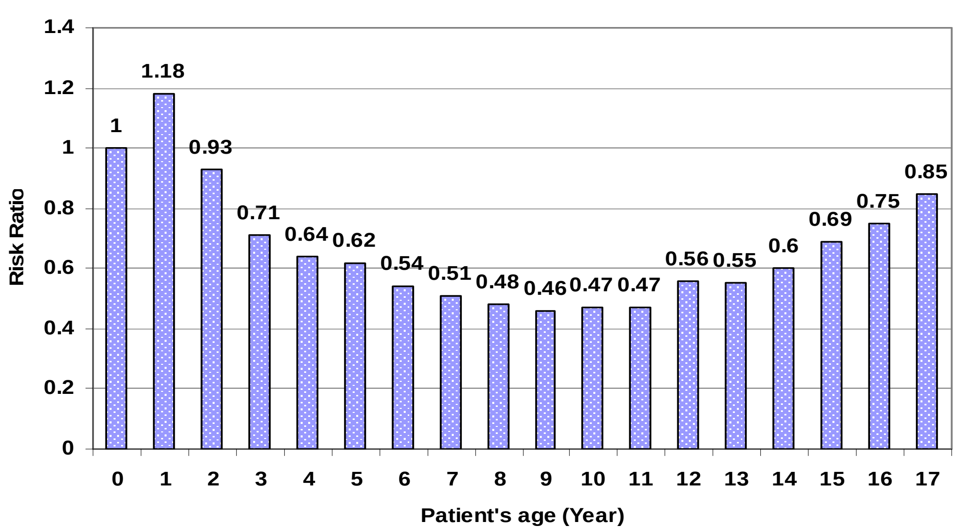


Figure 3. 38 Relative risk of sustaining a facial injury according to age (Multivariate analysis)

At the same time, multivariate analysis confirmed that there was a significant association between the relative risk of facial injury and deprivation; an increase in the relative risk of facial injury being associated with increasing social deprivation ($p<0.001$). SIMD 1 (most deprived) had the highest relative risk of 1.89, while in SIMD 5 (least deprived) the relative risk was 1.08 (Table 3. 35 and Figure 3. 39).

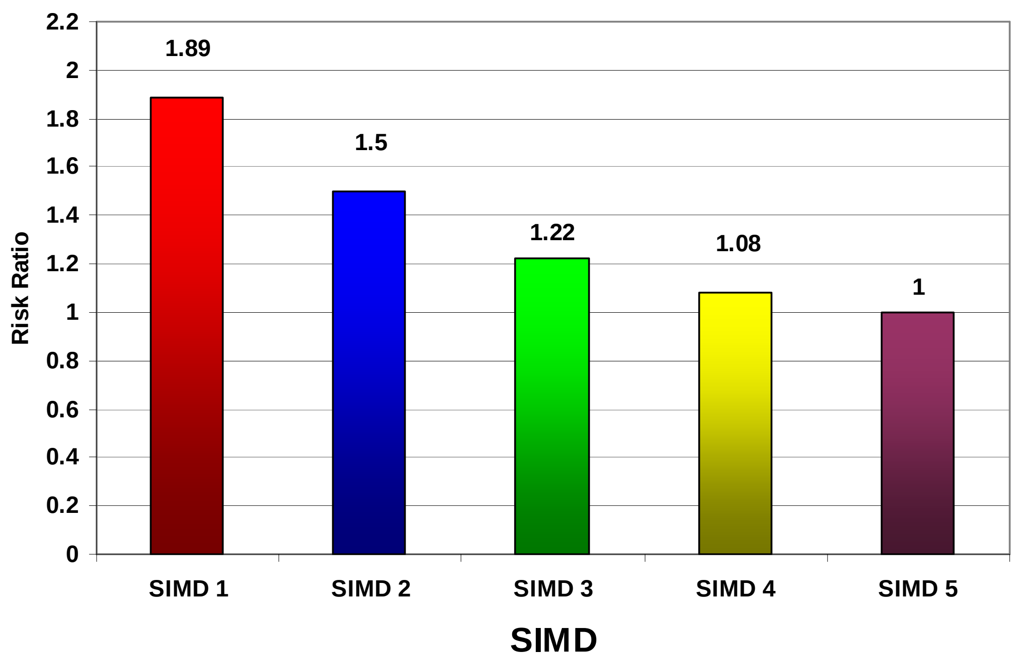


Figure 3. 39 Relative risk of sustaining a facial injury according to SIMD (Multivariate analysis)

The relative risk of facial injury varied significantly between individual Health Boards (areas) from 0.68 (Dumfries) to 1.76 (Grampian) (p < 0.001) (Table 3.36 and Figure 3. 40).

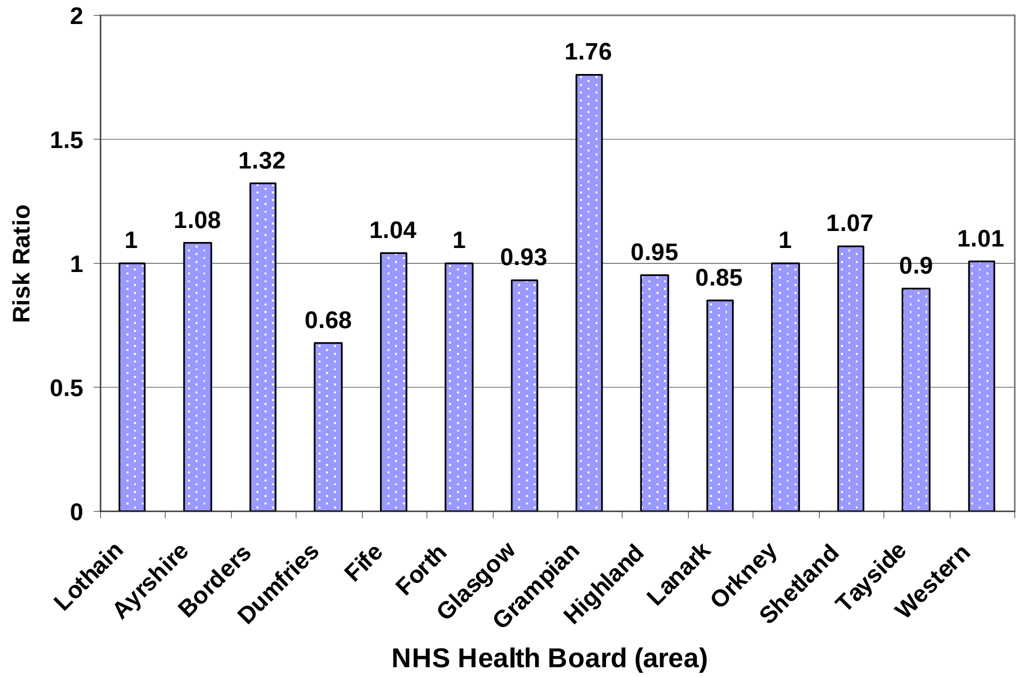


Figure 3. 40 Relative risk of sustaining a facial injury according to Health Board (Multivariate analysis)

3.6 Discussion

This part of the research revealed that paediatric facial injuries were not a common cause of childhood morbidity and accounted for only 0.5% of the total population under 17 years old in Scotland during the study period. However they still represent a considerable health burden and most injuries are preventable. The study also confirmed that more males than females sustained a facial injury which is consistent with other published studies and mirrors the patterns seen in adults (Conway et al., 2010).

It has been suggested by some studies that facial injury is less frequent in early life (up to approximately 5 years of age) (McGraw and Cole 1990) because of the protected environment of parental supervision. However, the findings of this study show quite a different picture; in this population the incidence and relative risk of injury were greatest at the extremes of age (<3 years of age and 15 - 17 years old). This finding is in agreement with two previous studies (Hutchison et al., 1998, Zerfowski and Bremerich 1998) and may be due to incidents occurring when young children are starting to become independently mobile and exploring their environment with a relative lack of co-ordination and later on in the teenage years when risk taking behaviour is more prevalent and often associated with alcohol, particularly in males.

In Scotland there was a considerable variation in the relative risk of facial injury by Health Board area. The relative risk (RR) of facial injury in Grampian Health Board was significantly higher than in other boards and this may reflect the fact that children attending the Emergency Department in this region may have travelled a considerable distance and may therefore be more likely to be admitted overnight for observation even with relatively minor injuries. The Royal Aberdeen Children's Hospital in Grampian receives patients from Highland, Tayside, Shetland and Orkney Health Board areas as well as Grampian and this may account for the lower relative risk of facial injury in some of these areas.

Facial injury in the adult population is most commonly sustained as a result of interpersonal violence, motor vehicle incidents, sports, falls or other non intentional injuries (Hutchison et al., 1998, Shaikh and Worrall 2002, Roccia et al., 2010). In the adult population in Scotland the most common cause is interpersonal violence (Hutchison et al., 1998, Oakey et al., 2008). In this study the aetiology varied considerably according to region with the vast majority of facial injuries in the paediatric population resulting from non-intentional injury.

There was a clear and significant association between the level of socio-economic deprivation and risk of facial injury. SIMD 1 (the most deprived) had a relative risk of 1.89 compared with 1.0 in SIMD 5 (the least deprived) ($p<0.001$). This endorses the point that the compositional characteristics of the population in residential areas affect the risk of injury to varying degrees. In the most deprived communities health promotion, prevention and parenting programmes should be implemented using culturally and educationally appropriate tools aiming to reduce all injuries with a special emphasis on non-intentional injuries, interpersonal violence and alcohol. However, this may not go far enough and political measures to improve the environment, community safety and community cohesion should also be considered.

This study is population based and included all denominators needed for direct calculation of injury rates in children for a given Health Board (area) or region. Despite this advantage there were inherent deficiencies due to the retrospective nature of the study. The study was designed to minimise the possibility of bias as all subjects were included with no exclusion categories. In addition the study covered all of Scotland including urban and rural areas, thereby providing a sample that reflected the general population as closely as possible. The main limitation of this study was that it did not include those subjects with facial injuries who were treated and discharged in the emergency departments or outpatient clinics, quite apart from those subjects who did not seek help for the treatment of their injuries. This study therefore underestimates the true extent of paediatric facial injury in Scotland as SMR01 entries are only generated for in-patient episodes. This indicates the need to develop a standardised method of collating and retrieving data for out-patient facial injury episodes.

3.7 Conclusion

The incidence of facial injuries requiring in-patient care in the paediatric population in Scotland has decreased over time from 5.5 per 1000 population in 2001 to 4.0 per 1000 population in 2009. Nevertheless facial injury requiring in-patient care in the Scottish paediatric population continues to represent a considerable social and healthcare burden particularly when the majority of injuries were due to preventable causes. There is a very strong association between social deprivation and facial injury with a significant increase in risk in more socially deprived communities. This risk is accentuated when alcohol is involved. There needs to be a significant investment by government in public health programs aimed at increasing knowledge and changing behaviour. The findings of this study should be disseminated to Health Boards and Trusts for consideration when developing future Health Improvement Programmes and Trust Implementation Plans so that appropriately targeted preventive programmes can be formulated.

Chapter IV – Paediatric Dental Injuries in Scotland

4.1 Abstract

Background: Dental injuries are a common occurrence in childhood. As a consequent of these injuries a large proportion of children report a negative impact on their daily life. To date the socio-demographic determinants of dental trauma among children in Scotland have not been described.

Aim: To describe, analyse and report the epidemiology, pattern and time trends of dental injuries and their socio-demographic determinants among primary one (P1) children in Scotland.

Method: Records of Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) and National Dental Inspection Programme (NDIP) for the period 1993 to 2007 were retrieved from the Scottish Dental Epidemiology Coordinating Committee (SDECC). Annual incidences of dental injuries were calculated by age, gender, Health Board and DEPCAT (Carstairs deprivation categories).

Results: 68,354 P1 children were examined and only 405 (0.6%) had suffered dental injuries with an overall incidence of 5.9 per 1000 population. There was a significant decrease in incidence over time (1993 figure three times greater than 2007). Virtually the same incidence rates were recorded for the two genders (M:F =1.13:1.0). Incidence varied significantly between Health Boards; the highest rate being reported in Dumfries (14.2 per 1000 population), which was 11 times greater than Ayrshire (1.3 per 1000 population). There was no significant association between risk of dental injuries and level of deprivation; in DEPCAT 1 (most affluent) the incidence rate was 6.4 per 1000 population, while in DEPCAT 7 (most deprived) the incidence rate was 5.7 per 1000 population.

Conclusion: The incidence of dental injuries was higher for those living in Dumfries but had significantly decreased since 1993. Gender and deprivation level had no effect on incidence and risk of dental injuries. More in-depth data is required to target interventions for prevention.

4.2 Introduction

In contrast with the epidemiology of facial injury in the paediatric population, traumatic dental injuries in children and adolescents have become one of the most frequent forms of treatment in dental practice. This suggests that traumatic dental injuries are common in childhood and are a significant cause of morbidity and presentation to hospital emergency departments. Several studies have reported that the prevalence of these injures has increased over the past few decades. It has been reported that about 35% of school age boys and about 25% of school age girls had sustained traumatic dental injury to their anterior teeth (Anderson and Ravn 1972, Hedegard and Stalhane 1973, Schatz and John 1994, Elisa et al., 2000).

In contrast to many other traumatic injuries, dental injuries are mostly irreversible and thus treatment will be likely to continue for the rest of the patient’s life (Glendor et al., 2001, Andreasen et al., 2007, Glendor 2008), and may have an impact on children’s quality of life, especially as the majority of dental injuries involve the anterior teeth (Rock et al., 1974, Stalhane and Hedegard 1975, Todd and Dodd 1985, Jackson et al., 2006, Andreasen et al., 2007, Aldrigui et al., 2011). The consequences of traumatic dental injury can vary from complete recovery to the loss of the tooth. At the same time dental injuries to children’s teeth can be very distressing for children as well as their parents.

Based on the literature, it would appear that in childhood many injuries result from falls and collisions which occur during playing and running or cycling, especially during the first years of childhood. This reaches a peak during the school years where accidents in the school playground are common. Traumatic dental injuries related to interpersonal violence tend to be more common in older individuals.

The relationship between socio-economic circumstances and dental caries in Scotland is well established. Those children resident in the most deprived areas experience more dental caries. There is a sequential rise in the number of decayed and missing teeth when moving from the more affluent to the most deprived areas. Five year old children from the most deprived areas, have more than 3 times the amount of dental caries experienced by those children living in the most affluent postcode sectors (Sweeney et al.,1999). This information with regard to dental injuries and its relationship with socio-economic circumstances which to date in Scotland has not yet been studied and any relationship established.

This chapter aims to study and report the pattern, time trends, and key socio-demographic determinants in children with traumatic dental injury in Scotland between 1993 and 2007. Section 4.3 of this chapter, will cover the aims and objectives of this study. Methods adopted to achieve these aims and objectives will be presented in Section 4.4 and will show all the results in Section 4.5. The discussion and conclusion of this study will be presented in Sections 4.6 and 4.7 of this chapter.

4.3 Aims and Objectives

By examining data pertaining to P1 (5 year old) children who had sustained dental injuries in Scotland between 1993 and 2007, this research aims to:

- Identify the demographics of traumatic dental injuries in Scotland

- Investigate the characteristics and trends of traumatic dental injuries over time in Scotland

- Assess whether differences in socio-demographics exist between traumatic dental injury cases

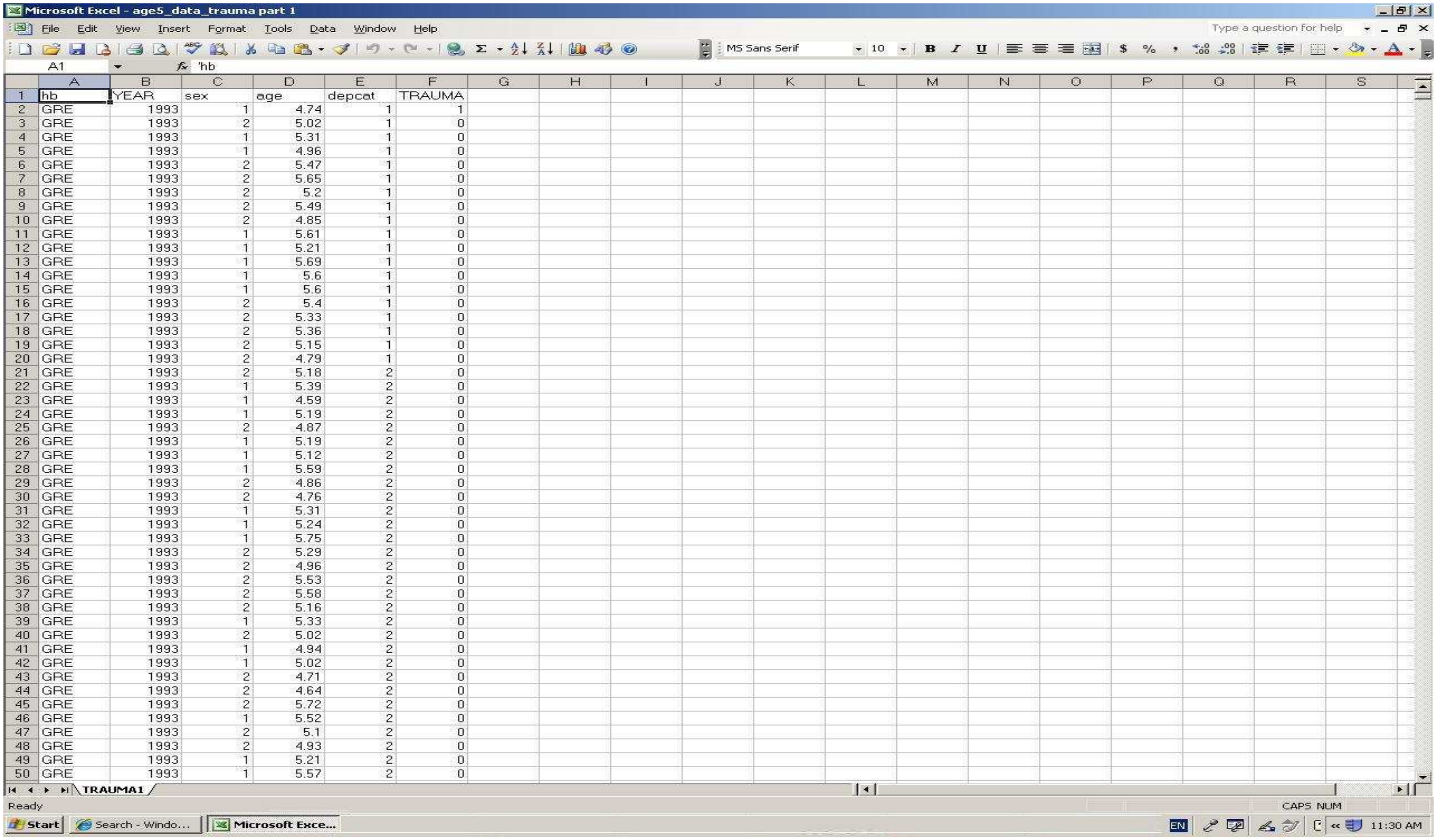
4.4 Methods

Initially, the Information and Statistics Division (ISD) of the NHS National Services Scotland (NHS NSS) was contacted regarding accessing the data concerning dental injuries of the Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) and National Dental Inspection Programme (NDIP). Data were requested electronically utilising a pre-formed data collection sheet based on the information available in the ISD (Figure 4. 1). All data was anonymised and no ethical approval was required. The study involved all dental injury records from SHBDEP and NDIP among P1 children for Scotland area. The complete data from SHBDEP records with a diagnostic code of dental injury were available up to the end of 2001. NDIP was used to retrieve the rest of the targeted period up to 2007.

4.4.1 Key data sources (1993-2001): Scottish Health Boards' Dental Epidemiological Programme (SHBDEP)

4.4.1.1 SHBDEP Background and purpose

This programme of surveys, which ran between 1987 and 2001, was managed by the Scottish Dental Epidemiology Coordinating Committee (SDECC). It was undertaken under the sponsorship of the Committee of Chief Administrative Dental Officers and Consultants in Dental Public Health Group (Scotland Group) and was a joint scheme between all fifteen Scottish NHS Boards (fourteen from 2006 - Figure 3. 1) and the Chief Scientist Office's Dental Health Services Research Unit. The aim of these surveys was to determine levels of tooth decay, to obtain a simple population measure of the level of oral cleanliness, and to investigate the impact of deprivation on the dental health of children in Scotland. The programme provided results for each NHS Board and allowed comparison between Boards and the monitoring of trends over time, specifically for the purposes of monitoring and planning oral health prevention programmes and dental services. It also allowed comparison of the results for Scotland with those of other parts of the UK.



	hb	YEAR	sex	age	depcat	TRAUMA
2	GRE	1993	1	4.74	1	1
3	GRE	1993	2	5.02	1	0
4	GRE	1993	1	5.31	1	0
5	GRE	1993	1	4.96	1	0
6	GRE	1993	2	5.47	1	0
7	GRE	1993	2	5.65	1	0
8	GRE	1993	2	5.2	1	0
9	GRE	1993	2	5.49	1	0
10	GRE	1993	2	4.85	1	0
11	GRE	1993	1	5.61	1	0
12	GRE	1993	1	5.21	1	0
13	GRE	1993	1	5.69	1	0
14	GRE	1993	1	5.6	1	0
15	GRE	1993	1	5.6	1	0
16	GRE	1993	2	5.4	1	0
17	GRE	1993	2	5.33	1	0
18	GRE	1993	2	5.36	1	0
19	GRE	1993	2	5.15	1	0
20	GRE	1993	2	4.79	1	0
21	GRE	1993	2	5.18	2	0
22	GRE	1993	1	5.39	2	0
23	GRE	1993	1	4.59	2	0
24	GRE	1993	1	5.19	2	0
25	GRE	1993	2	4.87	2	0
26	GRE	1993	1	5.19	2	0
27	GRE	1993	1	5.12	2	0
28	GRE	1993	1	5.59	2	0
29	GRE	1993	2	4.86	2	0
30	GRE	1993	2	4.76	2	0
31	GRE	1993	1	5.31	2	0
32	GRE	1993	1	5.24	2	0
33	GRE	1993	1	5.75	2	0
34	GRE	1993	2	5.29	2	0
35	GRE	1993	2	4.96	2	0
36	GRE	1993	2	5.53	2	0
37	GRE	1993	2	5.58	2	0
38	GRE	1993	2	5.16	2	0
39	GRE	1993	1	5.33	2	0
40	GRE	1993	2	5.02	2	0
41	GRE	1993	1	4.94	2	0
42	GRE	1993	1	5.02	2	0
43	GRE	1993	2	4.71	2	0
44	GRE	1993	2	4.64	2	0
45	GRE	1993	2	5.72	2	0
46	GRE	1993	1	5.52	2	0
47	GRE	1993	2	5.1	2	0
48	GRE	1993	2	4.93	2	0
49	GRE	1993	1	5.21	2	0
50	GRE	1993	1	5.57	2	0

Figure 4. 1 Electronic Data Set

4.4.1.2 SHBDEP Survey years/frequency

- 5-year-old children were examined every two years, in 1987, 1989, 1991, 1993, 1995, 1997, 1999 and 2001.
- 12-year-old children were examined every four years, in 1988, 1992, 1996 and 2000.
- 14-year-olds were also examined every four years, in 1990, 1994, and 1998.

4.4.1.3 SHBDEP Survey content

The SHBDEP collected data on dental caries (numbers of decayed, missing or filled teeth), oral cleanliness, and dental injuries. Deprivation status was assessed via postcode information for the child's area of residence. The information was collated and anonymised for reports.

4.4.1.4 SHBDEP Target population

School children aged 5 years, 12 years and 14 years, in local authority (not private) schools in Scotland.

4.4.1.5 SHBDEP Sample size

The SHBDEP used to sample around 8000 children across Scotland each year, of whom around 7000 were examined. Each NHS Board was required to identify the number of schools needed to obtain a representative sample of a given size (dependent on Board size) from the relevant age group population (5, 12 or 14 years). The sample sizes used provided adequate numbers to allow meaningful comparison between Boards.

4.4.1.6 SHBDEP Method of data collection

Data was collected by trained and calibrated Community Dental Service (CDS) dentists who followed a standard oral examination procedure for children. The last national survey took place in 1999/2000. Over the years SHBDEP built up a reliable data set which was crucial to the planning of dental services at both national and local levels. In 2003 the National Dental Inspection programme was instituted.

4.4.2 Key data sources (2003-2007): National Dental Inspection Programme (NDIP)

4.4.2.1 NDIP Background and purpose

NDIP was set up in 2002 and replaced the SHBDEP from 2003. This programme (NDIP) of surveys is managed by the Scottish Dental Epidemiology Coordinating Committee (SDECC). It is carried out under the auspices of the Committee of Chief Administrative Dental Officers/Consultants in Dental Public Health Group (CADO/CDPH Scotland Group) and is a joint scheme between all fifteen (fourteen from 2006) Scottish NHS Boards (Figure 3. 1) and the Dental Health Services Research Unit based at the University of Dundee - Scotland. NDIP work takes place across all areas of Scotland and involves the collaboration of many people and organisations, including the Consultants in Dental Public Health and the Chief Administrative Dental Officers Group, the Scottish Association of Community Dental Directors, Community Dental Officers, Scottish NHS Boards, Local Education Authorities, Community dental and oral health sections at local dental schools and universities, and the Information Services Division (ISD) of NHS National Services Scotland.

The main purposes of the programme are; to gather appropriate information in order to inform children and parents/carers of their dental/oral health status, and through appropriately anonymised and aggregated data, advise the Scottish Government, NHS Boards and other organisations concerned with children's health of the prevalence of oral disease, thereby providing an essential source of information for keeping track of the changes in the dental health of Scottish children.

4.4.2.2 NDIP Target population

School children in local authority (not private) schools in Scotland at two key child age groups: those entering school in primary one (P1) (around 5 years old), and those in primary seven (P7) (around 11 years old) before their move to secondary education.

4.4.2.3 NDIP Method of data collection

The Inspection Programme has two levels: a Basic Inspection (intended for all children) and a Detailed Inspection (for a representative sample of a specific age group in alternate years to assist in planning). The Basic Inspection involves a simple assessment of the mouth of each child using a light, mirror and ball-ended probe. Each child will be placed into one of three categories depending on the level of dental status and the treatment need, and a letter should then be sent to their parents.

One of three possible letters will be sent, each informing the parents about the state of dental health found in the mouth of their child at the time of the school inspection. The letters are as follows:

- Letter A - should seek immediate dental care on account of severe decay or abscess.
- Letter B - should seek dental care in the near future due to one or more of the following: presence or history of decay, a broken or damaged front tooth, tooth wear, poor oral hygiene or may require orthodontics (P7 only).
- Letter C - no obvious decay experience but they should continue to see the family dentist on a regular basis.

The results of the Basic Inspection are then anonymised and aggregated. They will be used to monitor the impact of local and national oral health improvement programmes, and to assist in the development of dental services. The Detailed Inspection is a more comprehensive assessment that involves recording the status of each surface of each tooth in accordance with international epidemiological conventions. The specific goals of the Detailed Inspection are to determine current levels of established tooth decay, to obtain a simple measure of the level of oral cleanliness and to determine the impact of deprivation on the dental health of primary one (P1) and seven (P7) children in Scotland.

4.4.2.4 NDIP Survey years/frequency

Since 2003 the Basic inspection has been undertaken annually for both Primary 1 and 7 pupils.

4.4.2.5 NDIP Sample size

Over 10,000 children in Scotland have a detailed inspection each year, while the aim is for all children in the target population to have a basic inspection.

4.4.3 Evaluation of Deprivation

In this part of the research the primary measure of neighbourhood deprivation used were the Carstairs deprivation categories (DEPCAT) which were attached to an individual's postal code. DEPCAT was the first index specifically developed for Scotland to measure socio-economic status. The Carstairs and Morris index was developed by Carstairs and Morris (Carstairs and Morris, 1991) and is a well established measure of socio-economic status in Scotland. Generally, DEPCAT ranges from a deprivation category (DEPCAT) of 1 representing the most affluent postcode, to DEPCAT 7 representing most deprived postcode.

4.4.4 Study sample

The targeted population who were included in this part of the research were primary one (P1) children in Scotland with dental injuries who were coded as participating in SHBDEP and NDIP between 1993 and 2007.

4.4.5 Statistical Analysis

After discussion and consultation with the statistician, SAS statistical software package version 9.1 (SAS Institute Inc., Cary, NC, USA) was adopted for use in data analysis. The data were subsequently coded, entered, processed and then analysed. The outcome of interest of this study was 'dental injuries'. Each variable in the study was examined first of all by frequency tabulation;

frequencies were presented as raw numbers and as percentages. Annual incidence rates by time (year), gender, Health Board and DEPCAT were calculated for the period of the study. A univariate logistic regression model was employed; the results for each variable were then expressed in the form of Pearson's chi-square (x^2) test and odds ratios (OR) with 95% confidence intervals. Odds ratios were calculated to give us a measure of how strongly the study variables are associated with the outcome compared to other variables.

4.5 Results

4.5.1 Data generated and its description

4.5.1.1 Study variables and demographic information

Between 1993 and 2007, a total of 68,354 P1 children were examined through SHBDEP and NDIP. Among them, only 405 cases were recorded with a diagnosis of dental injuries, with an overall incidence rate of 6 per 1000 population (Table 4. 1). 51% (n=35086) were males and 49% (n=33268) were females, the proportion of males sustained dental injuries was slightly higher than females (54% and 45% correspondingly; M; F = 1.2: 1) (Table 4. 2 and Figure 4. 2).

Table 4. 1 Incidence rate of dental injuries in Scotland (1993-2007)

Total Pop^n (P1) Examined (1993-2007)		Total Events (2001-2009)	
68354		405	
Total Pop^n	**Events_Sum**	**Pop^n_1000**	**Rate**
68354	405	68.354	5.93

Table 4. 2 Events of dental injuries by patient's gender

Gender		Dental injuries Yes	No	Total	Rate/1000
Female		185	33083	33268	5.6
	%	0.56	99.44	100.0	
	%	46	49	49	
Male		220	34866	35086	6.3
	%	0.63	99.37	100.0	
	%	54	51	51	
Total		405	67949	68354	6.0
	%	0.6	99.4	100.0	

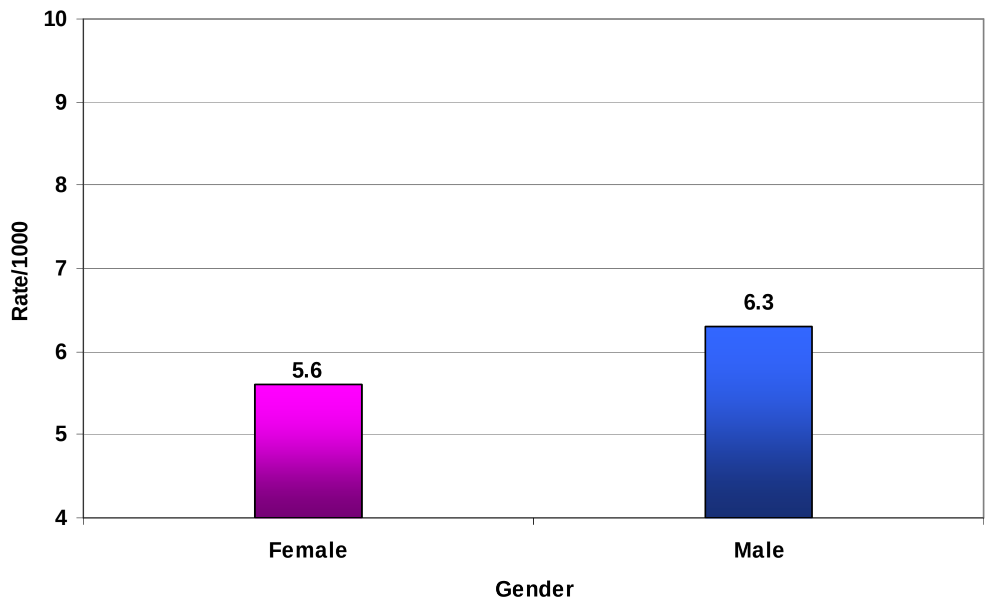


Figure 4. 2 Rates of Dental injuries over study period by patient's gender

Consistent with the aims and the methodology of this study, the Carstairs Deprivation Index (DEPCAT) was observed for each recruited case. Among DEPCAT categories the rate of incidence ranged between 5.5/1000 and 6.6/1000 (Table 4. 3 and Figure 4. 3).

Table 4. 3 Events of dental injuries according to DEPCAT

DEPCAT	*n*, of events (%)	Pop^n	Rate/1000
1	21 (0.64)	3301	6.4
2	48 (0.58)	8233	5.8
3	100 (0.62)	16077	6.2
4	94 (0.56)	16690	5.6
5	52 (0.55)	9456	5.5
6	52 (0.66)	7900	6.6
7	38 (0.57)	6697	5.7
Total	405	68354	5.9

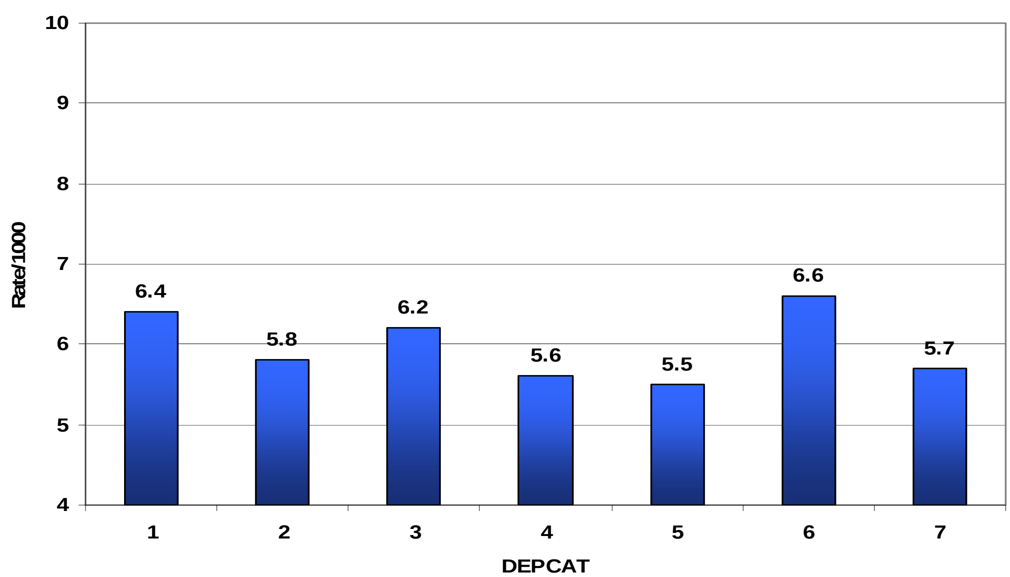


Figure 4. 3 Rates of Dental injuries over study period by DEPCAT

The incidence rates for sustaining dental injuries in each NHS Health Board (area) were documented and were varied. The highest rate was reported in Dumfries NHS Health Board (14.2/1000 population), which was 11 times greater than Ayrshire NHS Health Board (Table 4. 4 and Figure 4. 5).

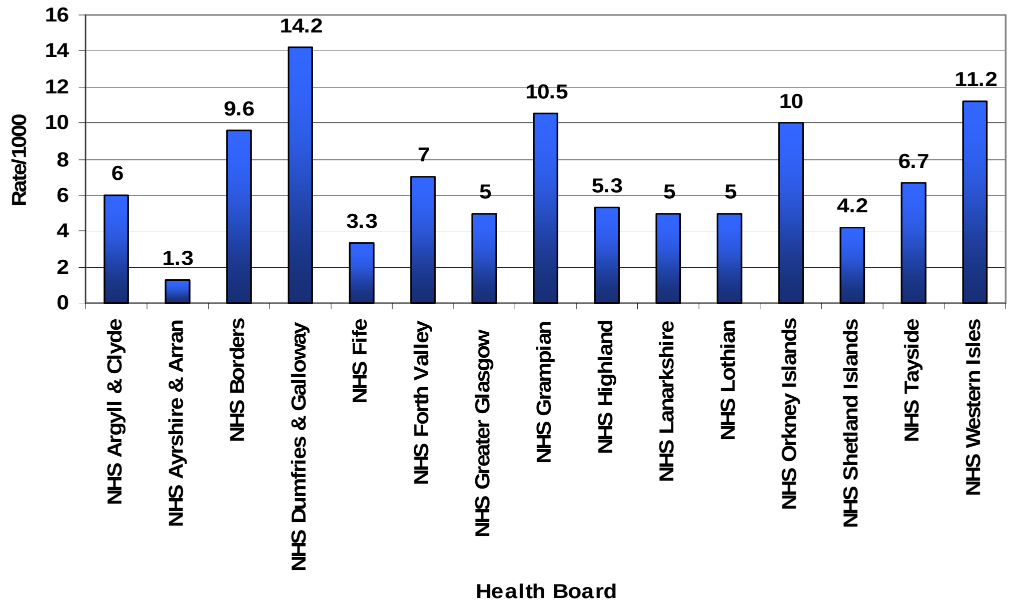


Figure 4. 4 Rates of Dental injuries over study period by Health Board (area)

Table 4. 4 Events of dental injuries according to Health Board (area)

Health Board	*n*, of events (%)	Pop^n	Rate/1000
NHS Argyll & Clyde	31 (0.6)	5149	6.0
NHS Ayrshire & Arran	5 (0.13)	3859	1.3
NHS Borders	22 (0.96)	2299	9.6
NHS Dumfries & Galloway	37 (1.42)	2613	14.2
NHS Fife	15 (0.33)	4514	3.3
NHS Forth Valley	23 (0.69)	3338	7.0
NHS Greater Glasgow	87 (0.48)	18163	5.0
NHS Grampian	46 (1.05)	4363	10.5
NHS Highland	16 (0.53)	3012	5.3
NHS Lanarkshire	29 (0.49)	5959	5.0
NHS Lothian	36 (0.50)	7248	5.0
NHS Orkney Islands	16 (1.0)	1621	10.0
NHS Shetland Islands	7 (0.42)	1684	4.2
NHS Tayside	23 (0.67)	3456	6.7
NHS Western Isles	12 (1.12)	1076	11.2
Total	405 (0.6)	68354	

The incidence rates of sustaining dental injuries among primary one (P1) children in Scotland were observed for each year from 1993-2007. The incidence rate has declined over time from 9.5 per 1000 population in 1993 to 3.0 per 1000 population in 2007 (1993 three times greater than 2007) (Table 4. 5 and Figure 4. 5).

Table 4. 5 Events of dental injuries over study period (1993-2007)

Study period (Year)	*n*, of events (%)	Pop^{n}	Rate/1000
1993	48 (0.95)	5073	9.5
1995	55 (0.88)	6235	8.8
1997	40 (0.61)	6565	6.1
1999	68 (1.01)	6766	10.1
2002	44 (0.45)	9747	4.5
2003	66 (0.60)	10956	6.0
2005	48 (0.44)	10945	4.4
2007	36 (0.30)	12067	3.0
Total	405	68354	

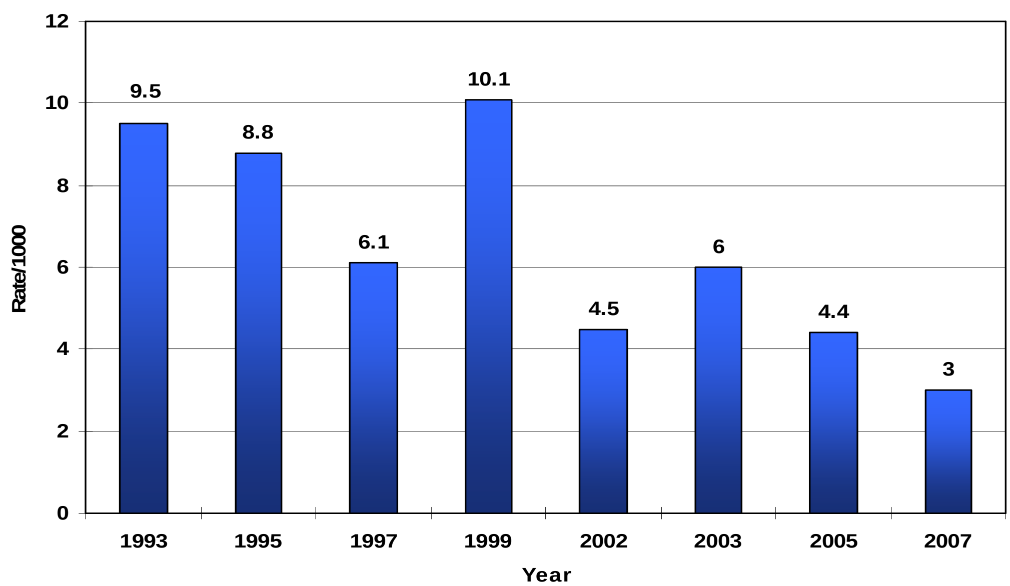


Figure 4. 5 Rates of Dental injuries - trends over time

4.5.1.2 Trends of dental injuries over time by study variables

4.5.1.2.1 Trends of dental injury over time by gender

Table 4. 6 and Figure 4. 6 show the trends and number of male and female patients who sustained dental injury over the study period. Both genders recorded a reduction in the percentage of cases over time. However males still have slightly higher rates over the study period (1993-2007).

Table 4. 6 Trends (Number & %) of dental injuries over time by patient's gender

Year	Patient Gender		Total
	Male(% within Year)	Female(% within Year)	
1993	29(1.1)	19(0.8)	48
1995	27(0.8)	28(0.9)	55
1997	19(0.6)	21(0.7)	40
1999	38(1.1)	30(0.9)	68
2002	25(0.5)	19(0.4)	44
2003	42(0.7)	24(0.5)	66
2005	17(0.3)	31(0.6)	48
2007	23(0.4)	13(0.2)	36
Total	220	185	405

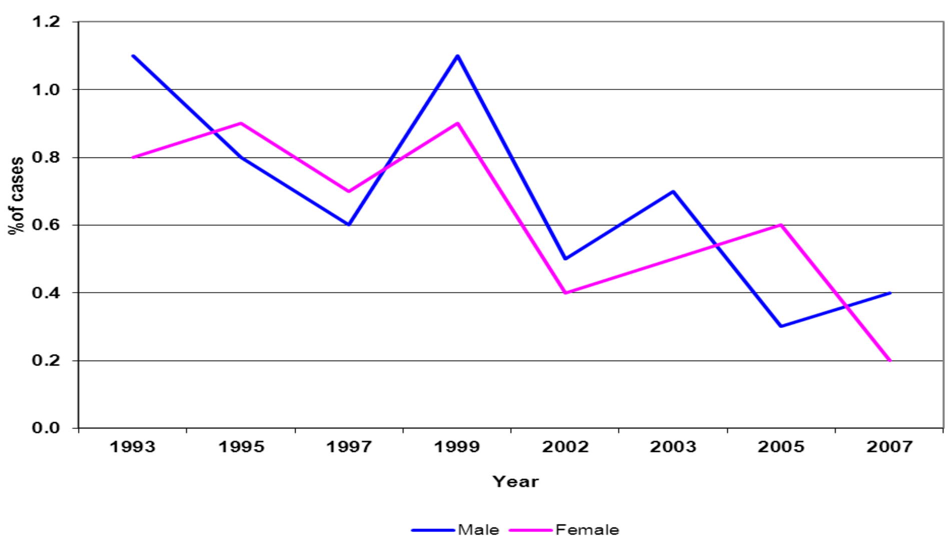


Figure 4. 6 Trends of dental injuries over time by patient's gender

4.5.1.2.2 Trends of dental injury over time by DEPCAT

Those sustaining dental injury over the period of the study with respect to the Carstairs Deprivation Index (DEPCAT) are shown in Table 4. 7 and Figure 4. 7. The majority of DEPCAT categories showed a reduction in the percentage of cases over time. Despite the differences in number of cases in each DEPCAT category, almost the same percentage in each category was recorded.

Table 4. 7 Trends (Number& %) of dental injuries over time by DEPCAT

Year	DEPCAT(% within Year)							Total
	DEPCAT 1	DEPCAT 2	DEPCAT 3	DEPCAT 4	DEPCAT 5	DEPCAT 6	DEPCAT 7	
1993	3(1.4)	11(2.3)	5(0.4)	11(1.0)	10(1.3)	2(0.3)	6(1.2)	48
1995	0(0.0)	6(0.9)	12(0.8)	9(0.6)	8(1.0)	10(1.4)	10(1.4)	55
1997	4(1.1)	1(0.1)	8(0.5)	14(0.9)	1(0.1)	5(0.7)	7(1.0)	40
1999	5(1.3)	6(0.6)	17(0.9)	19(1.1)	12(1.5)	5(0.8)	4(0.8)	68
2002	2(0.7)	4(0.4)	15(0.7)	11(0.4)	6(0.4)	5(0.4)	1(0.1)	44
2003	2(0.4)	8(0.5)	19(0.8)	17(0.7)	4(0.3)	12(0.9)	4(0.3)	66
2005	2(0.3)	8(0.5)	17(0.7)	7(0.2)	5(0.4)	6(0.6)	3(0.3)	48
2007	3(0.4)	4(0.3)	7(0.3)	6(0.2)	6(0.3)	7(0.4)	3(0.3)	36
Total	21	48	100	94	52	52	38	405

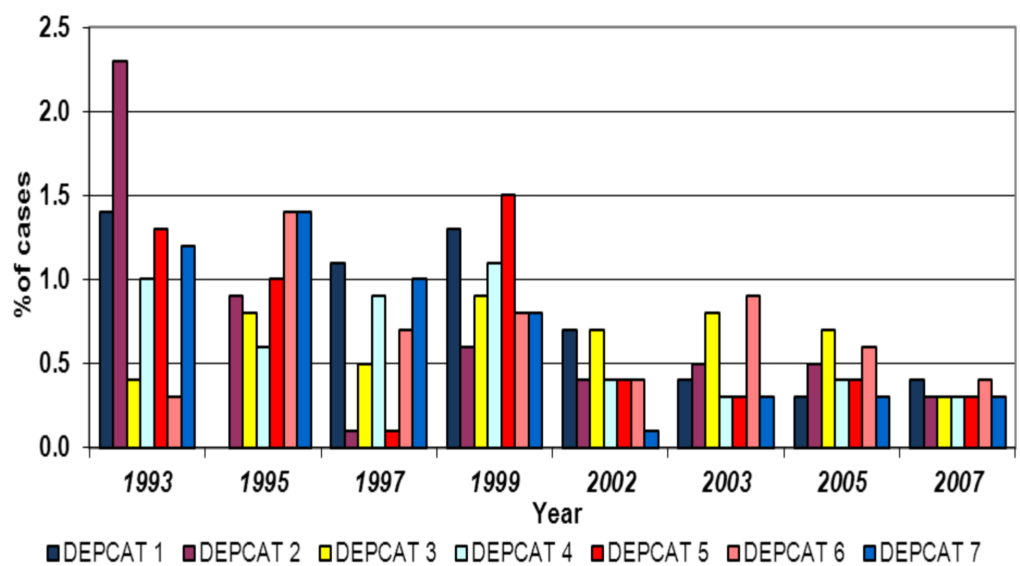


Figure 4. 7 Trends of dental injuries over time by DEPCAT

4.5.2 A univariate logistic regression analysis of study variables

4.5.2.1 Gender univariate results

Analysis showed that, sustaining of dental injuries were 13% more likely in males than females (OR= 1.13), which would indicate that being of male gender carries a slightly increased risk of dental injury. However, the statistical analysis did not show any statistical significance (p=0.227) (Figure 4. 8, Figure 4. 9 and Table 4.8).

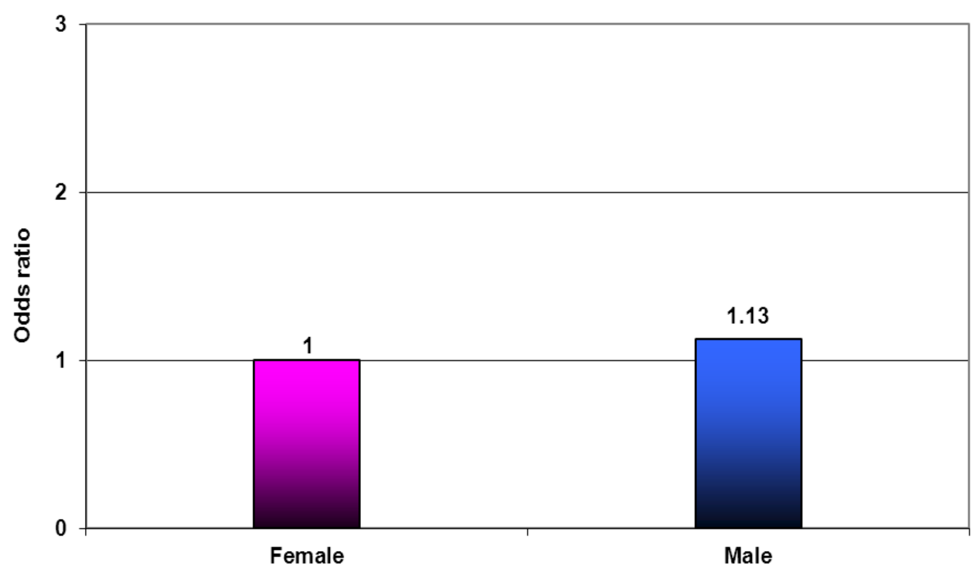


Figure 4. 8 Odds ratio of sustaining dental injury according to gender

The LOGISTIC Procedure

Model Information	
Data Set	WORK.TRAUMA
Response Variable	TRAUMA_
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	68354
Number of Observations Used	68354

Response Profile		
Ordered Value	**TRAUMA_**	**Total Frequency**
1 (No)	0	67949
2 (Yes)	1	405

Class Level Information		
Class	**Value**	**Design Variables**
gender	**1 (Male)**	1
	2 (Female)	0

Probability modelled is TRAUMA_=1.

Model Fit Statistics		
Criterion	**Intercept Only**	**Intercept and Covariates**
AIC	4963.736	4964.274
SC	4972.868	4982.539
-2 Log L	4961.736	4960.274

Testing Global Null Hypothesis: BETA=0			
Test	**Chi-Square**	**DF**	**Pr > ChiSq**
Likelihood Ratio	1.4615	1	0.2267
Score	1.4591	1	0.2271
Wald	1.4573	1	0.2274

Type 3 Analysis of Effects			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
Gender	1	1.4573	0.2274

Analysis of Maximum Likelihood Estimates						
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Pr > ChiSq**
Intercept		1	5.1864	0.0737	4948.6373	<.0001
Gender	**1**	1	-0.1208	0.1000	1.4573	0.2274

Odds Ratio Estimates			
Effect	**Point Estimate**	**95% Wald Confidence Limits**	
Gender; Male vs Female	1.128	0.927	1.373

Figure 4. 9 Output from logistic regression (Gender univariate analysis)

4.5.2.2 DEPCAT univariate results

Analysis showed that there was no statistically significant association between the risk of dental injuries and the level of deprivation; in DEPCAT 1 (most affluent) the odds ratio was 1 (reference), while in DEPCAT 7 (most deprived) the odds ratio was 0.89 (Figure 4. 10). This would indicate that there is a negative statistical association (*P = 0.96*) between level of deprivation and sustaining dental injuries (Figure 4. 11 and Table 4.8).

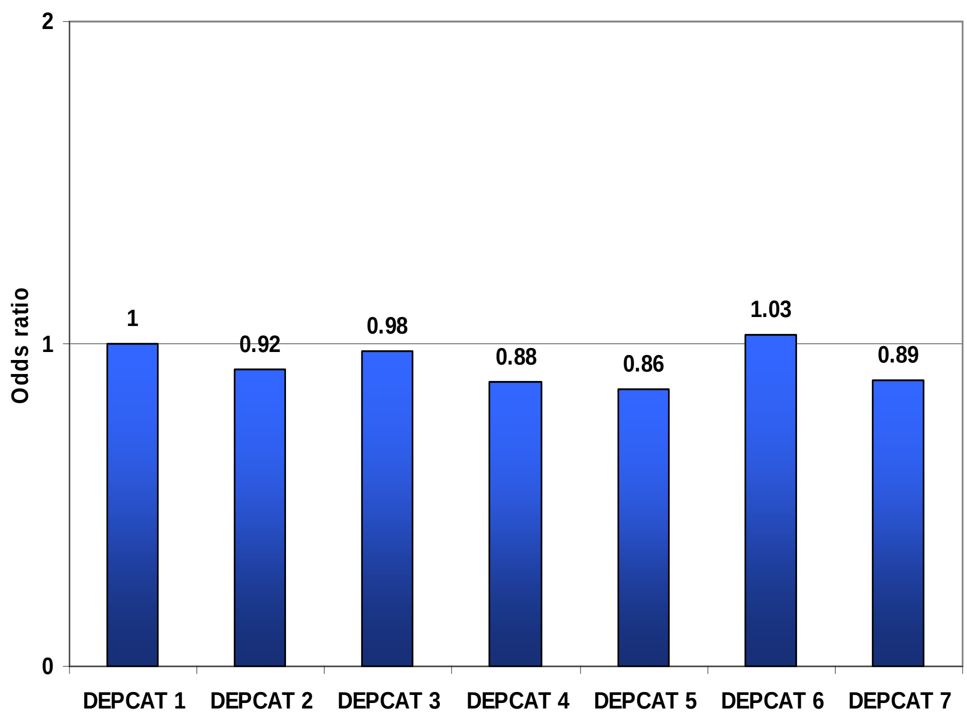


Figure 4. 10 Odds ratio of sustaining a dental injury according to DEPCAT

The LOGISTIC Procedure

Model Information	
Data Set	WORK.TRAUMA
Response Variable	TRAUMA_
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	68354
Number of Observations Used	68354

Response Profile		
Ordered Value	**TRAUMA_**	**Total Frequency**
1 (No)	0	67949
2 (Yes)	1	405

Probability modelled is TRAUMA_=1.

Model Fit Statistics		
Criterion	**Intercept Only**	**Intercept and Covariates**
AIC	4963.736	4964.274
SC	4972.868	4982.539
-2 Log L	4961.736	4960.274

Testing Global Null Hypothesis: BETA=0			
Test	**Chi-Square**	**DF**	**Pr > ChiSq**
Likelihood Ratio	1.5281	6	0.9576
Score	1.5423	6	0.9566
Wald	1.5402	6	0.9568

Type 3 Analysis of Effects			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
DEPCAT	6	1.5402	0.9568

Analysis of Maximum Likelihood Estimates						
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Pr > ChiSq**
Intercept		1	5.0511	0.2189	532.3734	<.0001
DEPCAT	**2**	1	0.0878	0.2624	0.1119	0.7380
DEPCAT	**3**	1	0.0227	0.2408	0.0089	0.9250
DEPCAT	**4**	1	0.1225	0.2421	0.2562	0.6128
DEPCAT	**5**	1	0.1466	0.2593	0.3194	0.5720
DEPCAT	**6**	1	-0.0343	0.2594	0.0175	0.8947
DEPCAT	**7**	1	0.1151	0.2727	0.1780	0.6731

Odds Ratio Estimates			
Effect	**Point Estimate**	**95% Wald Confidence Limits**	
DEPCAT 2 vs 1	0.916	0.548	1.532
DEPCAT 3 vs 1	0.978	0.610	1.567
DEPCAT 4 vs 1	0.885	0.550	1.422
DEPCAT 5 vs 1	0.864	0.520	1.436
DEPCAT 6 vs 1	1.035	0.622	1.721
DEPCAT 7 vs 1	0.891	0.522	1.521

Figure 4. 11 Output from logistic regression (DEPCAT univariate analysis)

4.5.2.3 Health Board (area) univariate results

Analysis showed that the rates for sustaining dental injuries in each NHS Health Board (areas) varied significantly. There was significant association between the risk of dental injuries and living in a certain area; for those who are living in Dumfries and Western Isles Health Boards the chance of having dental injury is higher than those living in Greater Glasgow Health Board area. At the same time children living in Greater Glasgow Health Board area are at higher risk of having a dental injuries compared to those who are living in Ayrshire, Fife and the Shetland Islands as shown in Figure 4. 12, Figure 4. 13 and Table 4.8.

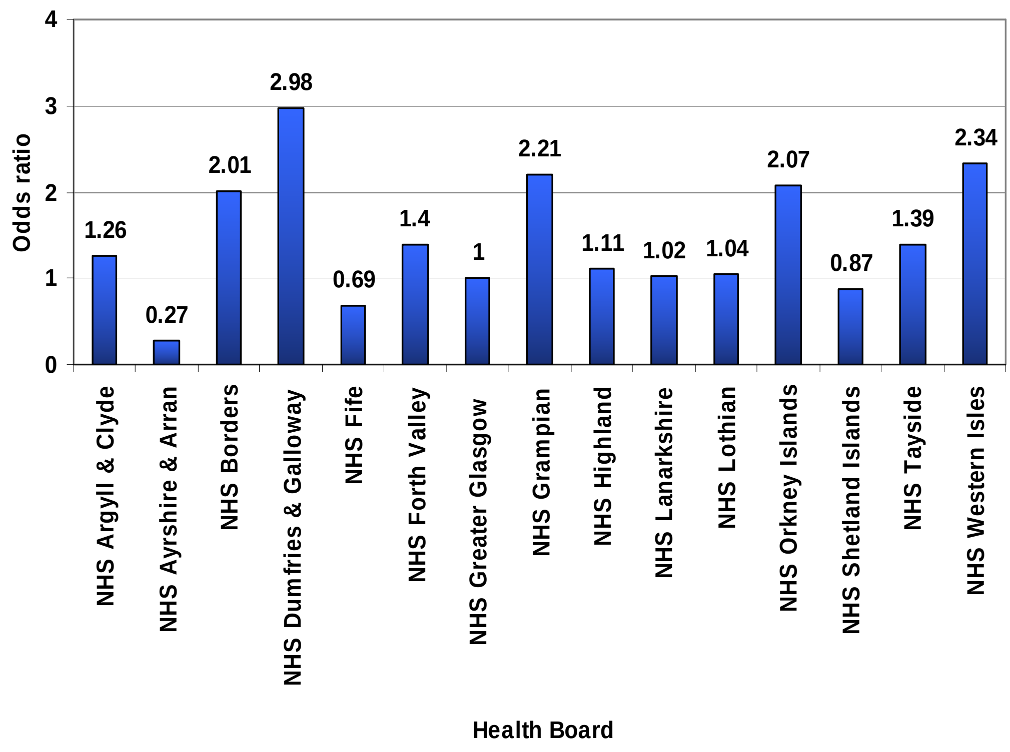


Figure 4. 12 Odds ratio sustaining dental injury according to Health Board

The LOGISTIC Procedure

Model Information	
Data Set	WORK.TRAUMA
Response Variable	TRAUMA_
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	68354
Number of Observations Used	68354

Response Profile		
Ordered Value	**TRAUMA_**	**Total Frequency**
1 (No)	0	67949
2 (Yes)	1	405

Probability modelled is TRAUMA_=1.

Model Fit Statistics		
Criterion	**Intercept Only**	**Intercept and Covariates**
AIC	4963.736	4909.968
SC	4972.868	5046.955
-2 Log L	4961.736	4879.968

Testing Global Null Hypothesis: BETA=0			
Test	**Chi-Square**	**DF**	**Pr > ChiSq**
Likelihood Ratio	81.7680	14	<.0001
Score	87.7449	14	<.0001
Wald	78.4370	14	<.0001

Type 3 Analysis of Effects			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
hb	14	78.4370	<.0001

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	5.3364	0.1075	2465.6760	<.0001
HB	**ARG**	1	-0.2299	0.2098	1.2011	0.2731
HB	**AYR**	1	1.3108	0.4602	8.1133	0.0044
HB	**BOR**	1	-0.6969	0.2397	8.4538	0.0036
HB	**DUM**	1	-1.0934	0.1974	30.6809	<.0001
HB	**FIF**	1	0.3671	0.2801	1.7183	0.1899
HB	**FOR**	1	-0.3657	0.2352	2.4173	0.1200
HB	**GRA**	1	-0.7948	0.1831	18.8435	<.0001
HB	**HIG**	1	-0.1040	0.2727	0.1454	0.7030
HB	**LAN**	1	-0.0159	0.2149	0.0055	0.9409
HB	**LOT**	1	-0.0364	0.1987	0.0337	0.8544
HB	**ORK**	1	-0.7281	0.2733	7.1002	0.0077
HB	**SHE**	1	0.1424	0.3937	0.1309	0.7175
HB	**TAY**	1	-0.3307	0.2352	1.9774	0.1597
HB	**WES**	1	-0.8515	0.3096	7.5675	0.0059

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
HB ARG vs GRE	1.258	0.834	1.898
HB AYR vs GRE	0.270	0.109	0.664
HB BOR vs GRE	2.007	1.255	3.211
HB DUM vs GRE	2.984	2.027	4.394
HB FIF vs GRE	0.693	0.400	1.199
HB FOR vs GRE	1.442	0.909	2.286
HB GRA vs GRE	2.214	1.546	3.170
HB HIG vs GRE	1.110	0.650	1.894
HB LAN vs GRE	1.016	0.667	1.548
HB LOT vs GRE	1.037	0.703	1.531
HB ORK vs GRE	2.071	1.212	3.539
HB SHE vs GRE	0.867	0.401	1.876
HB TAY vs GRE	1.392	0.878	2.207
HB WES vs GRE	2.343	1.277	4.298

Figure 4. 13 Output from logistic regression (Health Board univariate analysis)

Table 4.8 below summarises the results of this part of this research.

Table 4.8 Summary of logistic regression analysis of dental injuries by study variables: Gender, Year, Health Board and DEPCAT

Variable	Level	Events	POP	Rate (per1,000)	Odds ratio (95% CI)	*p* Value
Gender	Male	220	35086	6.3	1*	
	Female	185	33268	5.6	1.13 (0.93-1.37)	0.227
YEAR	1993	48	5073	9.5	1*	
	1995	55	6253	8.8	0.93 (0.63-1.37)	0.721
	1997	40	6565	6.1	0.64 (0.42-0.98)	0.039
	1999	68	6766	10.1	1.06 (0.73-1.54)	0.748
	2002	44	9747	4.5	0.47 (0.31-0.72)	<.001
	2003	66	10956	6.0	0.63 (0.44-0.92)	0.017
	2005	48	10945	4.4	0.46 (0.31-0.69)	<.001
	2007	36	12067	3.0	0.31 (0.20-0.48)	<.001
Health Board	Glasgow	87	18163	5.0	1*	
	Argyl & Clyde	31	5149	6.0	1.26 (0.83-1.90)	0.273
	Ayrshire	5	3859	1.3	0.27 (0.11-0.66)	0.004
	Borders	22	2299	9.6	2.01(1.25-3.21)	0.004
	Dumfries	37	2613	14.2	2.98 (2.03-4.39)	<.001
	Fife	15	4514	3.3	0.69 (0.40-1.20)	0.190
	Forth Valley	23	3338	7.0	1.44 (0.91-2.29)	0.120
	Grampian	46	4363	10.5	2.21 (1.55-3.17)	<.001
	Highland	16	3012	5.3	1.11 (0.65-1.89)	0.703
	Lanarkshire	29	5959	5.0	1.02 (0.67-1.55)	0.941
	Lothian	39	7248	5.0	1.04 (0.70-1.53)	0.854
	Orkney	16	1621	10.0	2.07 (1.21-3.54)	0.008
	Shetland	7	1684	4.2	0.87 (0.40-1.88)	0.718
	Tayside	23	3456	6.7	1.39 (.88-2.21)	0.160
	West Isles	12	1076	11.2	2.34(1.28-4.30)	0.006
DEPCAT	1(Most affluent)	21	3301	6.4	1*	
	2	48	8233	5.8	0.92 (0.55-1.53)	0.738
	3	100	16077	6.2	0.98 (0.61-1.57)	0.925
	4	94	16690	5.6	0.88 (0.55-1.42)	0.613
	5	52	9456	5.5	0.86 (0.52-1.44)	0.572
	6	52	7900	6.6	1.03 (0.62-1.72)	0.895
	7(Most deprived)	38	6697	5.7	0.89 (0.52-1.52)	0.673

*Reference.

4.6 Discussion

Traumatic dental injuries are currently seen as a public health problem because of their frequency and their wide occurrence among young patients during growth and development. Moreover, its treatment is often complex and expensive, and there may be irreversible sequelae, which will require treatment over the patient's entire life (Glendor et al., 2001, Andreasen et al., 2007, Glendor 2008), which may have an impact on children's quality of life, especially since the majority of dental trauma involves the anterior teeth (Rock et al., 1974, Stalhane and Hedegard 1975, Todd and Dodd 1985, Jackson et al., 2006, Andreasen et al., 2007, Aldrigui et al., 2011). However, this part of the research revealed that paediatric (P1 school children) dental injuries were not a common cause of childhood morbidity and were reported in only 0.6% of the total primary one population in Scotland (P1 recruited in SHBDEP and NDIP) during the study period 1993-2007. However they still represent a considerable health burden given that most injuries are preventable.

Gender has been pointed out as a predisposing factor in dental trauma (Andreasen et al., 2007), and several studies found a greater prevalence of trauma among male patients (Al-Jundi 2002, Sandalli et al., 2005, Ekanayake and Perea 2008, Eyuboglu et al., 2009, Robson et al., 2009). In this study, as in those conducted by other authors (Hargreaves et al., 1999, Kramer et al., 2003, Oliveira et al., 2007, Avsar and Topaloglu 2009, Jorge et al., 2009, de Amorim et al., 2011) no significant difference was found in the incidence rate of trauma between genders. In the past, boys were reported as being agitated, aggressive, and undisciplined, and girls by comparison calm and obedient, which may have resulted in higher trauma rates among boys in earlier decades. Now, children at an early age are encouraged to do whatever they want, regardless of gender.

Chapter III (Facial injuries in 1- 17 year olds) of this thesis shows that there was a clear and significant association between the level of socio-economic deprivation and risk of facial injury. This endorses the point that the compositional characteristics of the population in residential areas affect the risk of injury to varying degrees. This is in agreement with the results of another study (Marcenes and Murray 2001) which showed that traumatic dental injuries were higher and more common among lower socio-economic groups. In this study, there was no significant association between the risk of dental injuries and the level of deprivation. Nevertheless in the most deprived communities' health promotion, prevention and parenting programmes should be implemented using culturally and educationally appropriate tools, thus aiming to reduce all injuries. However, this may not go far enough and political measures to improve the environment, community safety and community cohesion should also be considered. This is the first time that such social variations in dental injuries have been investigated so comprehensively at a Scottish level.

In Scotland there was a considerable variation in the relative risk of facial injury by Health Board area as shown in chapter III of this thesis. With regard to dental injuries based on this study, the analysis shows that the rates for sustaining dental injuries in each NHS Health Board (area) varied significantly and there was a significant association between the risk of dental injuries and living in certain areas. In the absence of any knowledge about the place (location) and cause of injury it would be hard to determine why this variation should exist.

This study was based on data from two valued and respected epidemiological programmes in Scotland (SHBDEP and NDIP) which aim to assess every child's dental wellbeing so that children and their parents/carers can maintain oral health and take necessary steps to remedy any problems that may have arisen. These two programmes aim to fulfil these functions by providing an essential source of information for keeping track of any changes in the dental health of children in Scotland. The aim of these surveys originally was to determine levels of tooth decay, to obtain a simple population measure of the level of oral cleanliness, and to investigate the impact of deprivation on the dental health of children in Scotland. The programme provided results for each NHS Board. It allowed comparison between Boards and the monitoring of trends over time, for the purposes of monitoring and planning oral health prevention programmes and dental services. It also allowed comparison of the results for Scotland with those of other parts of the UK. This study was facilitated by the inclusion of postcode of residence in the personal data recorded for each child examined in the SHBDEP and NDIP surveys. It was encouraging that records collected in 1993-2007 of 5 year olds could be successfully linked to their respective DEPCAT Scores, and thus could include all the variables that were available for direct calculation of injury rates in children for a given Health Board (area) or region. In addition the study covered all of Scotland including urban and rural areas, thereby providing a sample that reflects the general population as closely as possible. Despite these advantages there were also inherent deficiencies due to the nature of the method of oral inspection during these programmes; the inspection involved a simple assessment of the mouth of each child using a light, mirror and probe. This means that only those dental injuries that were visible at the time of inspection were noted. This will result in an underestimation of the true extent of paediatric dental injury since it does not take into account previous injuries that have healed leaving no visible signs e.g. subluxation injuries. At the same time, the main limitation of this study was that it did not include those subjects with dental injuries who were registered at private schools (not target population of SHBDEP and NDIP), quite apart from those subjects who were not recruited (not sampled) in the two programmes. This study could therefore underestimate the true extent of paediatric dental injury in Scotland. Additionally and because of the nature and the main purpose of these two programmes (to determine levels of tooth decay) there is a lack of data about some important variables such as the place (location) and the cause of injury which makes it difficult to determine and report some explanations. This indicates that more in-depth data is required to target interventions for prevention and indicates the need to upgrade and develop a standardised method of collating and retrieving data for dental injury cases.

It is hoped that the results of this study will assist Health Boards and other relevant agencies in identifying areas of high dental need in their area so that preventive strategies can be effectively targeted.

4.7 Conclusion

This is the first time that social variations in dental injuries have been investigated so comprehensively at a Scottish level. This approach indicates that the prevalence of dental injuries in the paediatric population in Scotland (Primary one) is low (0.6%), at the same time the incidence of these injuries has decreased over time from 9.5 per 1000 population in 1993 to 3.0 per 1000 population in 2007. However, dental injury in the Scottish paediatric population continues to represent a considerable social and healthcare burden particularly when the majority of dental injuries are due to preventable causes. In addition, it was confirmed that there was no association between genders, social deprivation and dental injury at this age (Primary one). Nevertheless there needs to be a significant investment by government in public health programs aimed at prevention and increasing knowledge.

The findings of this study should be disseminated to Health Boards and Trusts for consideration when developing future Health Improvement Programmes and Trust Implementation Plans so that appropriately targeted preventive programmes can be formulated. Further research should be undertaken with regard to recruiting an inclusive sample (including children at private sector schools) to investigate those factors associated with deprivation which influence dental injuries in children. This study should be repeated for Primary 7 school children then the comparison between the two age groups will be possible, after which the need for further explorations of the association between dental injuries and deprivation in national surveys could be reviewed.

Chapter V – Dental Trauma and Treatment Outcomes at a Secondary Referral Centre

5.1 Abstract

Background: Traumatic dental injuries in children and adolescents are a common problem. Many answers to questions regarding the sequelae and prognosis of pulpal and endodontic treatment among traumatised teeth remain unclear.

AIM: To carry out a retrospective investigation of the occurrence of paediatric dental trauma and to explore the sequelae of non-surgical root canal treatment in traumatised anterior permanent teeth of patients referred to a secondary referral centre.

Method: Dental trauma database was used to randomly identify patients who had sustained dental trauma to their permanent anterior teeth between 1994 and 2008 which required pulpal treatment intervention. A data extraction form was designed, completed for each tooth, and then data was transcribed and processed. The association between treatment outcomes and clinical variables was studied using Fisher's exact test.

Results: 100 permanent teeth (72 patients) that required pulpal/root canal treatment interventions were identified. Dental trauma was frequent in the age group 9-11yrs (53.9%). Upper central incisors were the most common teeth involved (43.8%). Male: Female ratio was 2:1 with an average age at time of trauma of 10.31 yrs (SD 2.16 yrs). Home and immediate home environs were the commonest location (18%). Falls (34.8%) and injuries during sport/play (34.8%) were the commonest causes. The commonest injuries were enamel-dentine fracture with pulp exposure (34.8%) and avulsion (28%). 66.3% received a first treatment intervention less than 24 hours following the injury. Root canal treatment was the most frequent treatment provided especially for dental avulsion cases (100%). Treatment outcomes were split into three categories: Success (53.4%); Short-term success but long-term failure (35.6%); and Failure (11%). Significantly fewer failures occurred with: developing roots compared to completed roots ($P=0.05$); good quality temporary filling

material (*P<0.003*); no mobility (*P<0.001*); and <1 hour extra alveolar dry *time (P =0.02)*. No significance was reached with regard to: condition of root canal (*P=0.095*); extra alveolar time (*P=0.191*), and type of storage medium (*P=0.43*).

Conclusions: Stage of root development, quality of temporary filling, extra alveolar dry time and tooth mobility after commencement of treatment would appear to be significant factors in predicting the final treatment outcomes.

5.2 Introduction

Traumatic dental injuries in children and adolescents are a common problem and numerous studies have reported that the prevalence of these injuries has increased over the past few decades (Andreasen and Ravn 1972, Hedegard and Stalhane 1973, Schatz and Joho 1994, Elisa et al., 2000, Andreasen et al., 2007). One of the effects of dental trauma, on anterior teeth especially, is loss of vitality of the dental pulp (Andreason 1985 and Adeleke et al., 2007). The dental pulp can become injured or infected through trauma, especially if the dental pulp becomes inflamed, infected, necrotic or exposed (to the oral environment). In this case, the two clinical treatment options are pulp therapy or endodontic treatment in order to maintain the tooth functionally in the oral cavity (Friedman 2002 and Robert and Lian 2004).

Pulp therapy (also referred to as vital pulp therapy) is the treatment of the dental pulp in order to maintain or restore health to the pulp. However, if the pulp is infected or necrotic then root canal treatment ‘RCT’ (endodontic therapy) is the only treatment option if the tooth is to be retained in a healthy state. Furthermore, it is generally accepted that the most favourable prognosis for a tooth with an irreversibly necrotic pulp is obtained by providing appropriate endodontic therapy (Ørstavik and Ford 2008). The success and survival rates of root canal treatment are considered to be just less than that for implants; nevertheless it is considered preferable to keep the tooth rather than extract it and place an implant ‘superiority of tooth preservation’ (Scott et al., 2006). The clinicians must be conscious of treatment factors and prognostic factors that can influence outcome. A successful outcome for root canal treatment depends on sufficient disinfection and control of micro-organisms within the canal system combined with an adequate restoration that provides a satisfactory coronal seal (Briggs and Scott 1997, Peak et al., 2001).

The evaluation of the outcomes of both pulp therapy and endodontic treatment is an important aspect of treatment planning; not only it permit evaluation of clinical techniques, but it also allows for the development of criteria to further improve diagnostic, treatment, and post treatment recommendations (Lazarski et al., 2001). However, reports on treatment outcomes vary considerably (Robert et al., 2004). Many studies have been published where information was gathered on the outcomes of pulpal and initial root canal treatment. This large amount of literature is characterised by a great diversity in the reported outcomes. This diversity suggests that direct comparisons among these studies are problematic.

The outcomes of pulpal and non-surgical root canal treatment (NSRCT) have typically been studied using clinical signs and symptoms and/or radiographic findings. Another method of studying outcomes is through the use of epidemiological methods. However, most of these studies have dealt with NSRCT consequent to a variety of causes (such as dental decay or for a prosthetic purpose but excluding dental trauma) (Lazarski et al., 2001, Imura et al., 2007). Despite the vast information presented, answers to the main question related to the prognosis of pulpal and endodontic treatment among traumatised teeth have remained obscured by the non-standardised material and methods of many studies. A general review of these mixed studies could be ineffective and potentially ambiguous and inorder to answers questions on the sequelae and prognosis of pulpal and endodontic treatment among traumatised teeth really requires a new study that would focus on cases selected according to well defined criteria (Ørstavik and Ford 2008). Accordingly this study will attempt to consider all these factors.

This chapter aims to analyse the occurrence of paediatric dental trauma and to investigate the sequelae of pulpal and NSRCT to patients who have experienced dental trauma in their permanent anterior teeth and referred to a secondary referral centre (Glasgow Dental Hospital and School – GDHS). Section 5.3 of this chapter, will cover the aims and objectives of this study. Methods adopted to achieve these aims and objectives will be presented in Section 5.4 and the results in Section 5.5. The discussion and conclusion of this study will be presented in Sections 5.6 and 5.7 respectively.

5.3 Aims and Objectives

By using the dental trauma data base at Glasgow Dental Hospital and School to identify children and adolescents who have experienced dental trauma to their permanent anterior teeth between 1994 and 2008, this part of the research aims to:

- Evaluate the occurrence of traumatic dental injuries and their various etiologic factors in relation to the age and gender, teeth and number of teeth involved, and patterns of trauma

- Evaluate the success rate of pulpal/endodontic treatment

- Assess the treatment outcomes and to identify the various factors that could have influence on the outcomes

5.4 Methods

Ordinarily, outcome studies can be designed using one of two major approaches: prospective or retrospective. The former type allows for the randomisation of test subjects, standardisation of techniques and sampling methods, and the simultaneous study of multiple variables. Randomised controlled trials (RCTs) are case in point, and are considered as the gold standard by which all clinical research is judged (Hoskinson et al., 2002). However, the low failure rate and long follow-up times needed in endodontics makes the RCT study often underpowered and very expensive to conduct. Meta-analysis could be conducted if the studies were judged sufficiently similar in terms of types of patients, design and intervention, and is becoming used more frequently to achieve conclusions about clinical decisions. Systematic reviews may also include meta-analyses and/or cumulative meta-analysis. These permit appraisal of the additional contributions made by individual studies to the cumulatively pooled results of previous studies (Kojima et al., 2004, Moles et al., 2004). Alternatively, retrospective studies have the advantage of larger study populations, longer follow-up periods and are often protected from bias because data were often collected for reasons other than the study question. However, a major limitation is the lack of ability to randomise and standardise the experimental question, and they need both careful interpretation and cautious application of the results and conclusions to the general population.

This study will comprise two parts. The first part will be a review of patient case records for data gathering. The second part will consider outcomes of treatment and identify the main variables that could have influenced the outcomes.

5.4.1 Study sample

The targeted population who were included in this part of the research were all children and adolescents between 6 and <18 years of age who had sustained dental trauma to their anterior permanent teeth between 1994 and

2008 which required pulpal or NSRCT as a consequence. The study was undertaken at Glasgow Dental Hospital and School and used the trauma clinical database to identify cases. An accepted classification and categorisation system of dental trauma was adopted and given codes according to the type of trauma. This classification was a modification of the World Health Organisation's (WHO) classification. With regard to validity and reproducibility assessment for data extraction and to check for bias in data recorded in this study a sample from the records was reviewed randomly by a senior consultant under standardised conditions. There was agreement on common consensus for the collection of the data and the clinical and radiographic outcomes.

5.4.2 Statistical Analysis

Through discussion and consultation with the statistician, a retrospective study was designed to look at and to test different variables believed to affect the treatment outcomes. With the purpose of gathering all the target information from the records, an extraction data form was designed (Appendix 3). For each tooth, an extraction data form was completed and given a unique ID number. This form was designed to cover all the target information and variables including patient demographics. Confidentiality of patient information was considered throughout the study, as each patient name and contact details were kept concealed.

The SPSS statistical software programme was recommended for data analysis. Accordingly reading and training of how to use SPSS system were planned and completed in terms of self reading and attending University IT courses. Following completion of learning and training the congregated data were entered, processed, and analysed using SPSS statistical software programme (15.0 standard version recommended and offered by the University). All potential explanatory variables were cross tabulated with the outcome variables and Fisher's Exact test was used as appropriate to test for an association between the study variables and outcomes. Frequencies of categorical data are presented as raw numbers and as percentages. The level of statistical significance was set at $P < 0.05$.

In order to enable assessment of treatment outcomes simple assessment criteria were developed. Each included tooth was classified according to this criteria into one of the three groups; Success; Short term success but long term failure; or Failure.

5.5 Results

5.5.1 Data generated and its description

100 traumatised permanent teeth in a total of 72 patient case records (66% males) in the period between 1994 and 2008 were randomly selected and analysed. The average age of patients was 10.36years (SD 2.27), ranging between 6 and < 18 years and the trauma was recorded most frequently in the 9-11 year old age group (Figure 5.1).

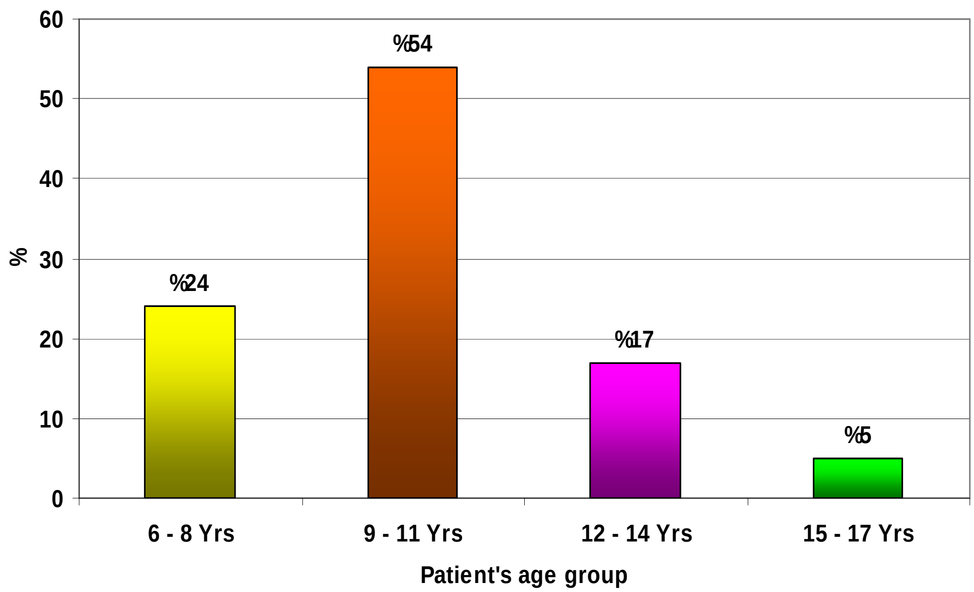


Figure 5.1 Proportion of dental trauma by patient's age

The most commonly traumatised teeth were the upper left and right central incisors (n= 43/100 and n= 40/100 respectively), while the lower teeth were less commonly traumatised (Table 5.1).

Table 5.1 Frequency of traumatised teeth by tooth ID

Tooth identification	Frequency
Upper Rt central incisor	40
Upper Rt lateral incisor	4
Upper Rt canine	1
Upper Lt central incisor	43
Upper Lt lateral incisor	7
Lower Lt central incisor	2
Lower Lt lateral incisor	1
Lower Rt central incisor	1
Lower Rt lateral incisor	1
Total	100

According to this study the injury mechanisms were varied. Falls and sports accidents were most common causes of dental trauma (36/100 and 32/100 correspondingly) (Table 5.2). The locations at which these injuries occurred were varied too. Apart from unspecified (35/100) the most frequent locations were house and school (18/100) and street (16/100) (Table 5.3).

Table 5.2 Dental trauma by injury mechanism

Cause	Frequency
Not Specified	1
Falls	36
Sports Accident	32
Road Traffic Accident	8
Assault	13
Cycling	2
Others	8
Total	100

Table 5.3 Dental trauma by location

Location	Frequency
Not Specified	35
House	18
School	18
Park	6
Street	16
Swimming pool	5
Others	2
Total	100

The incidence of secondary subsequent trauma was also considered in this study and it was only reported in 16 cases (Figure 5.2). All of these were male patients (*P=0.001*) (Figure 5.3).

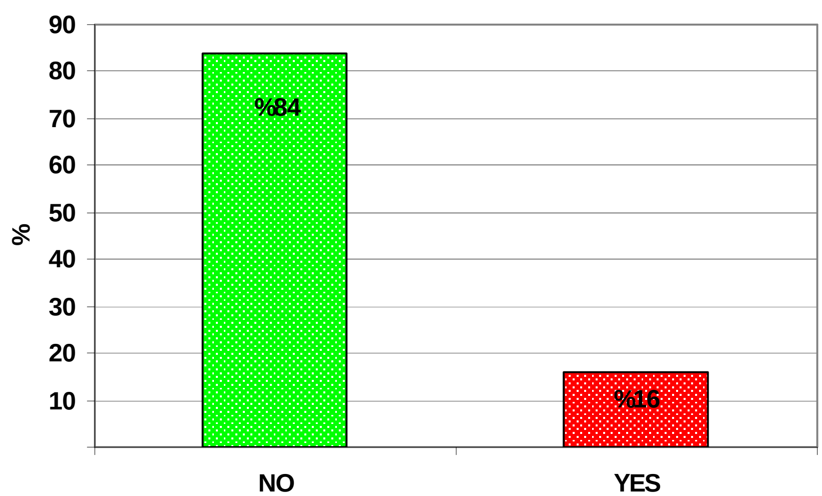


Figure 5.2 Secondary subsequent trauma

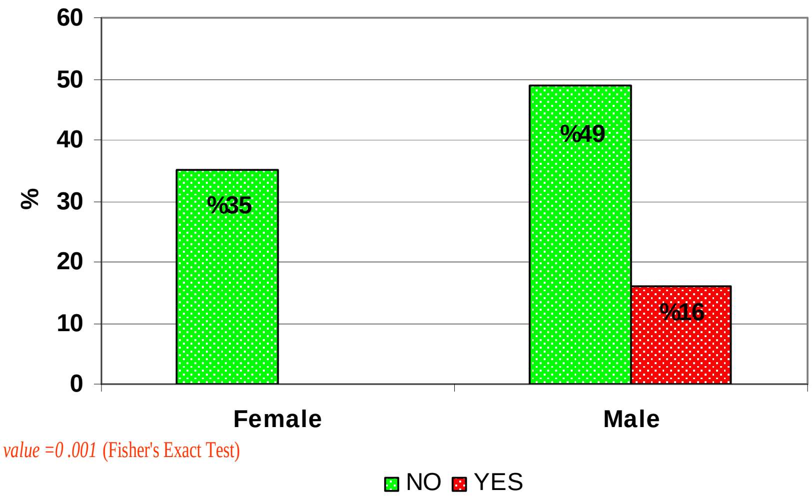


Figure 5.3 Secondary subsequent trauma by gender

At the first traumatic incident complicated crown fracture (comprising enamel dentine fracture with pulp exposure) and avulsion were the most observed types of dental trauma (31/100 and 27/100 respectively) (Table 5.4). In contrast complicated crown-root fracture was the most observed category (n=6) among those teeth that sustained subsequent trauma (Table 5. 5).

Table 5.4 Classification of dental trauma at 1st occasion

Trauma classification	Frequency
Avulsion	27
Avulsion + enamel dentine fracture	2
Avulsion + enamel dentine fracture with pulp exposure	1
Concussion	1
Enamel dentine fracture	18
Enamel dentine fracture + root fracture	3
Enamel dentine fracture with pulp exposure	31
Enamel dentine fracture with pulp exposure + root fracture	3
Extrusion	3
Intrusion	3
Lateral luxation	3
Root fracture at middle 1/3	1
Subluxation	3
Subluxation + enamel dentine fracture	1
Total	100

Table 5.5 Classification of dental trauma at 2nd occasion (subsequent trauma)

Trauma classification	Frequency
Avulsion	1
Enamel dentine fracture	3
Enamel dentine fracture with pulp exposure	4
Enamel dentine fracture with pulp exposure + root fracture	6
Lateral luxation	1
Root fracture at gingival level	1
Total	16
Cases without 2nd trauma	84
Total	100

At this stage of the study, only 11 teeth out of the 100 teeth were excluded from further analysis owing to no pulpal or root canal treatments (RCT) being provided, either for the reason that: the tooth was still under observation; pulpal or root canal treatment was not recommended at this stage; or the tooth was extracted/lost earlier (Table 5.6).

Table 5.6 Causes of excluding some teeth from further analysis

Cause	Frequency
Pulpal/RCT not recommended	7
Extraction of tooth before start pulpal or RCT	1
Tooth lost at time of trauma	2
Patient's medical condition (heart diseases).	1
Total	11

The majority of cases were treated by staff clinicians (n= 82, 92.1%) and only 7.9% (n=7) treated by undergraduate students. 59 teeth/89 were given initial pulpal/root treatment less than 24hrs following the trauma and 16 teeth/89 received initial pulpal/root treatment within 1-2 days. Some (n=4) had initial pulpal/root treatment between 3 days to 3 months after the trauma, while the remaining (n=2) received the initial treatment between one and two years or longer after trauma (Table 5.7).

Table 5.7 Time elapsed after trauma until receiving the initial pulpal/root treatment

Time elapsed	Frequency
<24hrs	59
1 -2 days later	16
3 days – 1 week later	2
>1 – 4 weeks later	1
1 – 3 months later	1
1 – <2 years later	1
2 years & longer	1
Not specified	8
Total	89

Some 61 cases (68.5%) required a 2nd treatment intervention, either because of failure of the 1st intervention or because it had been recommended to avoid any further complication (Figure 5.4).

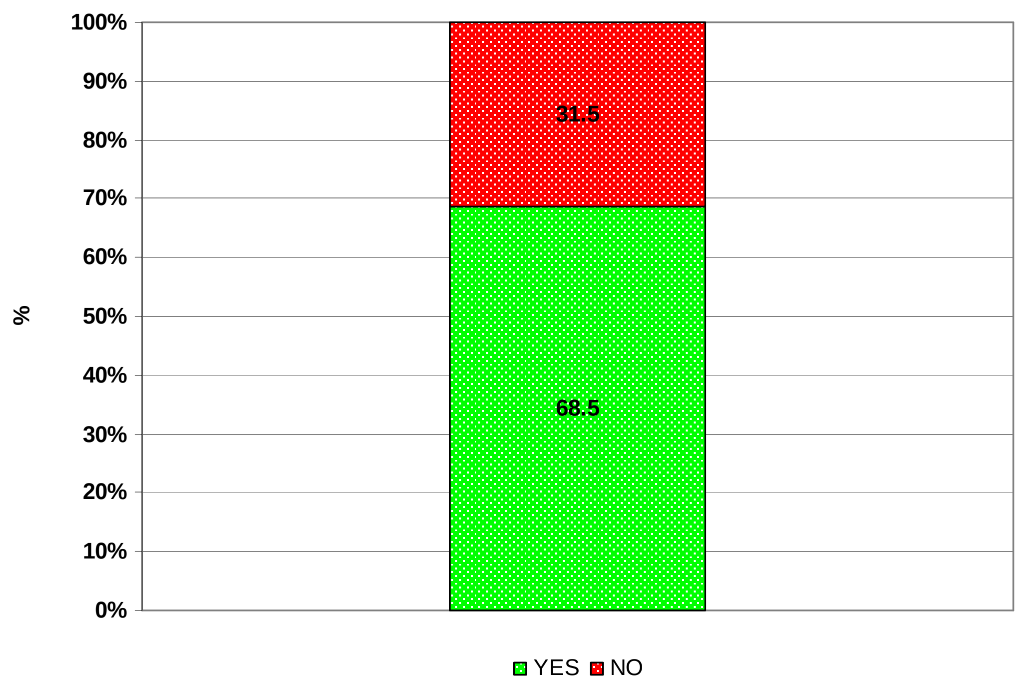


Figure 5.4 Proportion of teeth requiring a 2nd treatment intervention

A total of 83 teeth had completely or nearly complete formed apices and six teeth had devolping roots at the time of their initial presentation.

Some 21 (23.6%) cases suffered trauma on a single tooth; 43 (48.3%) on two teeth; and 25 (28.1%) on three or more teeth (Table 5.8). In more than half of them (51.7%, n=46) soft tissue injury was also recorded (Table 5.9).

Table 5.8 Number of teeth injured at initial injury (same occasion)

	Frequency	%
One	21	23.6
Two	43	48.3
Three or more	25	28.1
Total	89	100.0

Table 5.9 Dental trauma associated with soft tissue injury

	Frequency	%
Not cited	22	24.7
Yes	46	51.7
No	21	23.6
Total	89	100.0

Extra Alveolar time (EAT) and extra alveolar dry time (EADT) for 25 dental avulsion cases were recorded. Less than 1 hour of EAT was recorded in 4 of cases, between 1-2 hours of EAT was recorded in 5 of the cases and rest of cases had EAT more than 2 hours. EADT was varied, in some cases it was not specified (n=10) and for the rest of the cases (n= 15) was specified and were in the <2hrs category as shown in Table 5.10.

Table 5.10 Extra alveolar dry time (EADT)

	Frequency
<1hr	6
1hr-2hrs	3
>2hrs	6
Not specified	10
Total	25
Other categories of trauma	64
Total	89

The storage medium for avulsed teeth varied; the majority of the cases were stored in milk (12/25), 6 teeth were kept dry and 7 teeth were stored in non-specified medium. Of all trauma cases 36 teeth were splinted. The choice of splinting option depended on the type of trauma, for instance it was 100% (n=25) in avulsion cases. In contrast, not surprisingly it was 0.00% (n= 31) in enamel dentine fractures with pulp exposure. Among the 36 splinted cases, the most common type of splint was a composite/wire splint (n=19). In all, the fixation period varied as shown in Table 5.11.

Table 5.11 Splinting period

Splinting period	Frequency
< 2 wks	12
2-3 wks	9
3-6 wks	5
>6 wks	3
Not cited	7
Total	36
Non-splinted cases	53
Total	89

For teeth that required pulpal or root canal dressing, the selection of dressing was based on the type of trauma; non-setting calcium hydroxide (NS-$Ca(OH)_2$) was the most common dressing used (n= 62/89) especially in the avulsion cases (Table 5.12). Conventional calcium hydroxide ($Ca(OH)_2$) was the most common choice as a pulpal dressing in cases with enamel dentine fracture (ED#) and in cases of enamel dentine fracture with pulp exposure (EDP#) as shown in Table 5.12. At the same time, in 10 cases Ledermix followed by NS-$Ca(OH)_2$ was used (Table 5.12). These were all avulsion cases. Altogether, the frequency and the number of times the root canal dressings were changed was varied; in some of the cases it depended on the stage of root formation while in others it was the dryness of the root canal. Teeth with incompletely developed roots, and teeth with canals which failed to dry required a longer dressing time and more changes of dressing.

Table 5.12 Trauma classification and Type of pulpal/canal dressing (s) used

Trauma classification	Type of pulpal/canal dressing (s) used					
	Not cited	NS- $Ca(OH)_2$	Ledermix	Ledermix then NS-$Ca(OH)_2$	$Ca(OH)_2$	Total
ED#	1	7	0	1	7	16
EDP#	0	19	0	4	8	31
ED# + root #	0	3	0	0	0	3
Subluxation	0	2	0	0	0	2
Lateral luxation	0	2	0	0	0	2
Intrusion	0	3	0	0	0	3
Avulsion	0	17	0	5	0	22
EDP# + root#	0	2	1	0	0	3
Avulsion + EDP#	0	1	0	0	0	1
Extrusion	0	3	0	0	0	3
Subluxation + ED#	0	1	0	0	0	1
Avulsion + ED#	0	2	0	0	0	2
Total	1	62	1	10	15	89

A total number of 70 cases (70/89 teeth) required root filling; among them only 39 cases had their final filling when the data was extracted. Gutta-Percha was the most common type of root filling material used (n=36). Likewise, the time to the final obturation was varied; ranging from one month to two years and more. The majority of them (n=24) were obturated 2 years or longer after the date of the initial trauma.

5.5.2 Effects of main study variables on treatment outcomes

In order to enable assessment of treatment outcomes some simple assessment criteria were established (Table 5.13). Each included tooth was classified according to this criteria into one of the following categories:

1. Success.
2. Short-term success/long-term failure.
3. Failure

Table 5.13 Criteria for treatment outcome assessment

Outcome	Criteria
Success	A tooth is still in the patient mouth. Tooth exhibits normal tooth function. No evidence of subjective discomfort. Absence of clinical signs and symptoms. Absence of painful response to percussion or palpation. Absence of abscess and sinus tract of pulpal or endodontic origin. Absence of tooth mobility. Presence of normal periradicular and periodontal ligament structure. Positive pulp test after operative treatment (For teeth treated only with vital pulp therapy).
Short-term success /long term failure	A tooth has healed partially with no symptoms and will be retained until the patient is old enough to receive further treatment such as implant or fixed prosthesis.
Failure	Tooth extracted or due for extraction (only because of failure of the treatment that dealt with initial trauma). Development of periradicular lesion which was not present before or its size has increased after operative treatment. Presence of swelling or sinus tract related to the tooth being evaluated. Presence of periradicular radiolucency that developed after completion of treatment. Presence of trauma complication such as widespread root resorption necessitating extraction.

At this stage of the study, a further 16 out of the 89 teeth were excluded from any further analysis because their treatment outcomes were unable to be assessed. Either they failed to return without completion of treatment or just after treatment completion, or because they were currently still under treatment without completion of root treatment (Table 5.14).

Table 5.14 Excluded cases

	Frequency
Not excluded	73
Failure to return after the start of treatment	6
Failed to return after completion of treatment	7
Treatment still ongoing	3
Total	89

According to the assessment criteria (Table 5.13) and including all trauma cathegories; the over all success rate was 53.4% (n=39/73), while short-term success and long-term failure was 35.6% (n=26/73) and failure of the treatment was recorded in only 8 cases (11%) (Table 5.15 and Figure 5.5).

Table 5.15 Treatment outcomes

		Frequency	%
	Success	39	53.4
	Short-term success and long-term failure	26	35.6
	Failure	8	11.0
	Total	73	100.0
	Excluded cases	16	
Total		89	

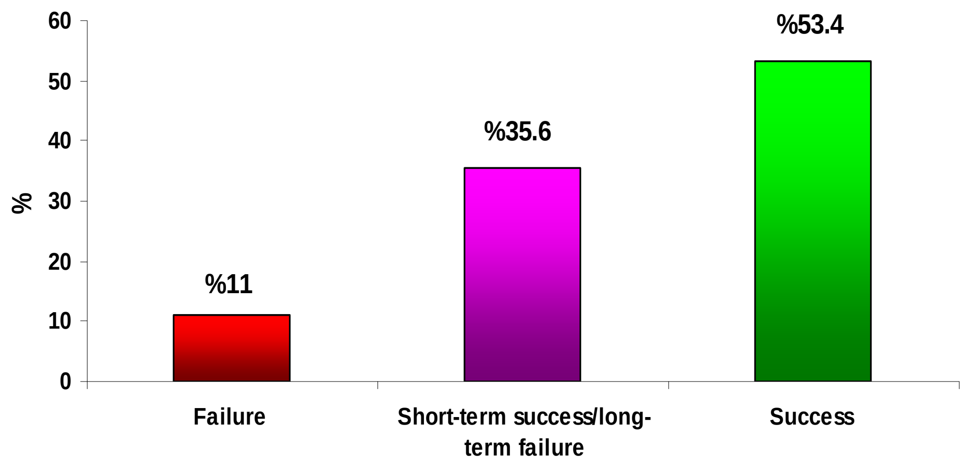


Figure 5.5 Treatment outcomes

5.5.2.1 Effects of subsequent trauma on treatment outcomes

Fisher's test was applied to examine the association of subsequent trauma on the same tooth at a different time with treatment outcomes. The test did not reveal a significant association (*P =0.069*). However in the quantitative analysis a trend was observed; among cases that had sustained subsequent trauma the success was recorded in only 4 cases, compared to 35 success cases in those with no subsequent trauma (Table 5.16).

Table 5.16 Sustaining of subsequent trauma by treatment outcomes

	Treatment outcomes			
	Failure	Short-term success/long-term failure	Success	Total
No	5	19	35	59
Yes	3	7	4	14
Total	8	26	39	73

P value =0.069(Fisher's Exact Test)

5.5.2.2 Initial trauma classification and treatment outcomes

Treatment outcomes were in direct relation to the severity of trauma (*P<0.000* -Table 5.17 and Table 5. 18). In cases where the pulp remained intact or was not involved (not severe cases) at the time of trauma (i.e. ED# cases) the success rate was high (n=13/15). Conversely, in other more severe cases such as complicated crown root fractures or dental avulsion the failure rate was higher (Table 5. 18).

Table 5.17 Initial trauma classification and treatment outcomes

Initial trauma classification		Treatment outcomes			Total
		Failure	Short-term success/long-term failure	Success	
ED#		1	1	13	15
EDP#		0	5	16	21
Subluxation		0	1	1	2
Lateral luxation		0	0	2	2
Intrusion		0	3	0	3
Extrusion		0	3	0	3
Total		1	13	32	46
	%	2 %	28%	70%	100 %

#=fracture, P value <0.000 Fisher's Exact Test

Table 5. 18 Dental avulsion and combination injuries with treatment outcomes

Initial trauma classification		Treatment outcomes			Total
		Failure	Short-term success/long-term failure	Success	
ED# + root #		2	0	0	2
EDP# + root #		0	1	2	3
Subluxation + ED#		0	0	1	1
Avulsion		4	10	4	18
Avulsion + EDP#		0	1	0	1
Avulsion + ED#		1	1	0	2
Total		7	13	7	27
	%	26%	48%	26%	100%

#=fracture, P value <0.000 Fisher's Exact Test

5.5.2.3 Time elapsed (since trauma) until receiving initial pulpal/root treatment and treatment outcomes

The analysis did not demonstrate any statistical significant association between time elapsed until receiving initial treatment and outcome (*P = 0.195*). However, this does not mean that time elapsed until receiving initial pulpal/root treatment was not clinically significant, as the most successful treatments were recorded among those cases which received the treatment within a short period of time (1 to 2 days) as shown in Table 5.19.

Table 5.19 Time elapsed until receiving initial pulpal/root treatment and treatment outcomes

Time elapsed		Treatment outcomes			Total
		Failure	Short-term success/long-term failure	Success	
Not Specified		0	4	3	7
<24hrs		7	20	23	50
1 -2 days later		1	1	10	12
3 days – 1week later		0	0	2	2
1month – 3months later		0	0	1	1
1year – 2 years later		0	1	0	1
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value =0.195 Fisher's Exact Test

5.5.2.4 Stage of root formation and treatment outcomes

Table 5.20 shows the association between the stage of root formation and the treatment outcomes. The teeth with completely formed roots had the highest failure rate (n=8/37) compared to teeth with developing roots (n=0/5) (n=73, *P value =0.050*).

Table 5.20 Stage of root formation and treatment outcomes

Stage of root formation		Treatment outcomes: Failure	Short-term success/long-term failure	Success	Total
2/4(Parallel)		0	0	1	1
3/4 (Convergent)		0	2	2	4
4/4 (completely formed but apex still open)		0	14	17	31
4/4 (completely formed)		8	10	19	37
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value =0.050 Fisher's Exact Test

5.5.2.5 Number of changes of pulpal/canal dressings and treatment outcomes

Statistically there was no significant association between the number of changes of root canal dressings and treatment outcomes (*n=73, P =0.09*) (Table 5.21).

Table 5.21 Number of changes of root canal dressing and treatment outcomes

Dressing changes		Treatment outcomes: Failure	Short-term success/long-term failure	Success	Total
Not Specified		3	2	6	11
1 time		1	0	11	12
2 times		0	1	2	3
3 - 5 times		1	12	13	26
5 and more		3	11	7	21
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value =0.09 Fisher's Exact Test

5.5.2.6 Quality of temporary filling (TF), and mobility recorded after dressing and treatment outcomes

There was a statistically significant association between good quality of temporary fillings ‘in term of stability’ (*P=0.03*), and tooth mobility after the commencement of dressings (*p<0.001*) with treatment outcomes as shown in Table 5.22 and Table 5.23 correspondingly.

Table 5.22 Quality of temporary filling and treatment outcomes

Quality of temporary fillings		Treatment outcomes: Failure	Short-term success/long-term failure	Success	Total
Not cited		2	11	5	18
Good sealing (in place)		2	10	24	36
Not good (TF became loose >1time)		4	5	10	19
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value =0.03 Fisher's Exact Test

Table 5.23 Mobility recorded after dressing and treatment outcomes

Mobility after dressing		Treatment outcomes: Failure	Short-term success/long-term failure	Success	Total
Not Specified		1	3	2	6
No mobility		1	8	34	43
Yes- Grade I		5	13	3	21
Yes- Grade II		1	2	0	3
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value <0.001 Fisher's Exact Test
Grade I : Slightly more than normal. Grade II: Moderately more than normal

5.5.2.7 Root canal condition after dressings and treatment outcomes

Fifty six out of 73 cases required root canal intervention either as a conventional root canal treatment or an apexification procedure, either as an initial or secondary intervention. The condition of the root canal after starting the process of canal dressing was considered to see if there was any association between the condition of the root canal and the treatment outcomes. Analysis shows that there was no statistical association between the condition of the root canal and the treatment outcomes (*n=56, P =0.095*) - Table 5.24. However descriptively good success rate was observed among cases reported as dry and clean (n=17/30), compared to those reported with pus or any sign of infection where the success rate was zero (Table 5.24).

Table 5.24 Root canal condition and treatment outcomes

Root canal condition		Treatment outcomes			Total
		Failure	Short-term success/long-term failure	Success	
Not cited		4	12	7	23
Dry and clean		2	11	17	30
Pus (or any sing of infection)		1	2	0	3
Total		7	25	24	56
	%	12.5%	44.6%	42.9%	100.0%

P value =0.095 Fisher's Exact Test

5.5.2.8 Use of traumatised tooth as an abutment and treatment outcomes

Some traumatised teeth were ultimately chosen as abutments for a fixed or removable partial prosthesis or had orthodontic treatment after the main trauma treatment. Statistical analysis shows that there was no significant association between utilisation of treated traumatised teeth and the treatment outcomes *(P =0.629)* - Table 5.25. However, quantitatively a higher success rate was observed among cases that were not used as abutments (Table 5.25).

Table 5.25 Use of traumatised teeth and treatment outcomes

Abutment use		Treatment outcomes			Total
		Failure	Short-term success/long-term failure	Success	
None		7	22	36	65
Fixed prosthesis		0	1	1	2
Removable prosthesis		0	1	0	1
Orthodontic treatment		1	2	2	5
Total		8	26	39	73
	%	11.0%	35.6%	53.4%	100.0%

P value =0.629 Fisher's Exact Test

5.5.2.9 Extra alveolar time, extra alveolar dry time, and storage medium for avulsed teeth and treatment outcomes

A total number of 21 cases were documented as avulsed or avulsed plus other trauma such as ED# or EDP#. The extra alveolar time (EAT), extra alveolar dry time (EADT), and type of storage medium were studied to identify any association with treatment outcomes. The analysis shows significant association between EADT and treatment outcomes (n=21, *P=0.02*). No statistical significance associations were reported with EAT (n=21, *P=0.191*) or with storage medium (n=21, *P=0.434*).

5.5.3 Summary of study results

5.5.3.1 Data description

- This descriptive retrospective study carried out at Glasgow Dental Hospital and School, looked at different variables believed to affect treatment outcomes of traumatized teeth. 100 traumatised permanent teeth in the period between 1994 and 2008 in a total of 72 patient case records were randomly selected and studied

- 66.6% were male and 33.3% were female (M: F, 2: 1). The range of patient's age was between 6-17 years of age with an average of 10.36years (SD 2.272)

- Trauma was recorded most frequently in the age group 9 -11 years old and the most commonly traumatised teeth were the upper left and right central incisors (n=43 and n=40 respectively)

- Falls and sport accidents were the most common causes of dental trauma (n=36 and n=32 correspondingly)

- Locations and incidences of injury mechanisms were varied. Non-specified locations accounted for 35 cases, while the second most frequent locations were streets and houses (n=18)

- 16 cases sustained subsequent trauma on the same tooth; all of these were male patients (*P=0.001*)

- Enamel-dentine fracture with pulp exposure and avulsion were the most observed types of dental trauma (n=31and n= 27respectively). In contrast; complicated crown-root fracture was the most observed category among those teeth that sustained subsequent trauma

- 59 cases were given their initial pulpal/root canal treatment less than 24hrs after the incident (trauma), while other cases received their treatment between 2 days and 2 years or longer after the trauma

- 68.5% of the cases required a second treatment intervention (RCT), either because of failure of the first intervention (Pulpal treatment) or because it was recommended to avoid any further complications and sequelae

- 23.6% of the cases suffered trauma on a single tooth, 48.3% on two teeth and 28.1% suffered trauma on three or more teeth. In more than half (51.7%) soft tissue injury was recorded

- Among dental avulsion cases less than 1 hour of EAT was recorded in 16% (n=4/25) and >1hour to < 2 hours in 20% (n=5/25). Less than 1 hour of EADT was recorded in 24% (n=6/25), non-specified EADT was recorded in 40% (n=10/25) of the cases. The majority of the cases were stored in milk (48%), while 24% were kept dry, and the rest where non-specified

- A selection of pulpal/root dressings was based on the type of trauma; non-setting calcium hydroxide (NS-$Ca(OH)_2$) was the most frequently used dressing (67.4%), especially in the avulsion cases. Conventional calcium hydroxide ($Ca(OH)_2$) was the 2nd most frequently used choice

(16.9%) and was commonly used as a pulpal dressing, especially in cases with enamel dentine fracture.

- 78.7% of cases required root filling either as a first or secondary intervention

5.5.3.2 Effects of the main study variables on treatment outcomes

- The success rate was 53.4%, while failure of the treatment was recorded in only 11% of the cases. Just above a third of the cases (35.6%) were documented as short-term success and long-term failure

- No significance association was recorded between sustaining subsequent trauma and the treatment outcomes ($P = 0.069$)

- The type of trauma and severity was statistically associated with the treatment outcomes ($P < 0.001$)

- There was no statistical relationship between treatment outcomes and the time elapsed (since trauma) until receiving initial treatment ($P = 0.195$)

- Teeth with completely formed apices at the time of presentation showed a statistically significantly greater failure rate (21.6 %) compared to teeth with developing roots (0.0%) ($P = 0.050$)

- The number of times pulpal/root canal dressings were changed was not statistically associated with treatment outcomes ($P = 0.09$)

- The quality of temporary filling was significant factors in determining the treatment outcomes ($P = 0.03$)

- Tooth mobility after intra canal dressing was statistically associated with treatment outcomes ($P < 0.001$)

- The condition of the root canal after commencement of intra canal dressing was not statistically associated with treatment outcomes (*P =0.095*)

- EADT was a significant associated factor (*P= 0.02*) with the outcomes of the treatment among the avulsed cases or avulsed along with other trauma such as enamel dentine fracture or enamel dentine fracture with pulp exposure

5.6 Discussion

Dental trauma is a public health problem because of the frequency and wide occurrence, especially among children and adolescents. Furthermore, treatment is often complex, and there may be irreversible sequelae, which will require treatment over the patient's entire life (Glendor et al, 2001, Andreasen et al., 2007, Glendor 2008).

Age is a well-documented risk factor, and although dental trauma has been observed in all age groups, this study has shown that more traumatic incidents occur in the 9–11 year age group. These results are in agreement with other studies (Zerman and Cacalleri 1993, Petti and Tarsitany 1996, Brown 2002, Lihong et al., 2005). In the past there was a belief that higher trauma rates among boys were because boys were agitated, aggressive, and undisciplined, and girls, generally calm and obedient. However, the common belief now is that the potential for dental trauma in dependant on the individual's activity and living environment (Glendor 2008). However, gender is still recognised as a predisposing factor in dental trauma (Andreasen et al., 2007), and several studies have found a greater prevalence of trauma among male patients (Al-Jundi 2002, Sandalli et al., 2005, Ekanayake and Perea 2009, Eyuboglu et al., 2009). In this study, as in those conducted by other authors (Forsberg and Tedestam 1990, Oulis and Berdouses 1996, Hamilton et al., 1997, Wilson et al., 1997, Marcenes et al., 2000, Bastone et al., 2000, Rajab 2003, Traebert et al., 2003) there was a male predominance.

In this study most of the trauma cases involved more than one tooth (76.4%), and this is probably explained by the size of a child's oral cavity and the fact that multiple dental injuries are associated with sports, falls, and traffic accidents; frequent in this age group. The most commonly affected teeth in previous studies were the maxillary incisors (Rock et al., 1974, Stalhane and Hedegard 1975, Andreasen 1981, Saröglu and Sönmez 2002, Andreasen et al., 2007), our study findings confirmed that. One possible explanation for this is the protective effect of the maxilla on the mandible during occlusion and the fact that the maxilla is rigidly fixed to the cranium, while the mandible is flexible, tending to reduce the force of impact on the mandible (Oliveira et al., 2007, Eyuboglu et al., 2009).

According to Glendor (Glendor 2008, Glendor 2009), the environment and the type of activities are the most important factors in dental trauma occurrence. In this study falls were the most frequent cause of trauma, followed by sports accidents. These findings support the general findings that etiologic factors vary according to age group studied (Rodd and Chesham 1997, Marcenes et al., 1999, Andreasen et al., 2007). Based on our results, the places where most injuries occurred were the house and the school. This highlights the importance of the development and implementation of educational programmes to teach parents and teachers how to prevent falls and how to provide first aid in dental trauma incidents.

In this study a simple criteria was developed based upon clinical and radiographic findings and upon every clinician's 'goal'; namely to retain and keep a traumatised tooth healthy in the mouth, at least until after growth of the facial skeleton has ceased. This criteria was used to assess the treatment outcomes of the trauma cases. As this study included all types of trauma and because there are fundamental differences in prognosis between the types of trauma sustained these simple criteria may affect the results. Assessment criteria must be considered further across the field of traumatic dental injury research.

The most frequent type of trauma sustained was enamel dentine fracture with pulp exposure, which confirms the results of previous studies (Sanches et al., 1990, Al-Jundi 2002, Rajab 2003, Traebert et al., 2003). Other studies (Borsse´n and Holm 2000, Skaara and Jacabsen 2005) found that the most prevalent injury was subluxation. These differences may be explained by the methods, examination procedures, and diagnostic criteria adopted in different studies. Mild trauma, such as concussion and subluxation, is not frequently reported because they are less serious and heal faster, and often result in parents not seeking treatment (McTigue 2000). In this study the type of trauma was a strong predictor of treatment outcomes and significantly associated with the treatment outcomes ($P < 0.001$). These findings support the evidence based treatment guidelines for dental trauma findings (Andreasen et al., 2009).

The trauma classified in this study as 'subsequent trauma' is a complicating factor of trauma in permanent tooth and may lead to greater treatment complexity and increased costs (Pissiotis et al., 2007). Subsequent trauma on the same tooth at different times was reported in about 16% of the cases, and all these cases were males which emphasises the discussion about Male: Female prevalence. In this study no significant association was recorded between sustaining subsequent trauma and treatment outcomes ($P = 0.069$). However, subsequent trauma was responsible for some of the complications (failures) noticed in this study. This highlights the fact that further studies need to evaluate what factors are associated with dental trauma recurrence.

Timely referral to the dentist after any traumatic injury and seeking immediate care for the injured tooth is of great importance. In this study about 66% of cases were referred to the clinic and received the first treatment/intervention within one day following trauma. Lack of information about dental trauma and the consequences of such trauma might be responsible for delays in seeking dental care after a traumatic injury for the other cases. Delays in treatment can have adverse effects on long-term outcomes (Hamilton et al., 1997, Batstone et al., 2004). Although Andreasen in his review article indicated that delayed treatment for uncomplicated tooth fractures with no luxation injuries could be significant (Andreasen et al., 2002). In this study no significant association between time elapsed until receiving initial treatment and outcome. However, this does not mean that time elapsed until receiving initial pulpal/root treatment was not clinically significant, as the most successful treatments were recorded among those cases which received early treatment (1 to 2 days after injury).

Based on this study the stage of root development appears to be a strong outcome predictor for all types of dental trauma, and it affects both pulpal and periodontal healing. Teeth with completely formed apices at the time of presentation showed greater failure rate compared to teeth with developing roots ($P = 0.05$). This is not surprising since a good blood supply is essential for pulpal healing and thus the size of the apical foramen is directly related to the revascularization potential of the affected tooth (Andreasen et al., 2007).

Based on the results of this study, type of trauma and its severity (combination injuries) was significantly associated with the treatment outcomes; a combination injury caused by dental trauma represents a very complex healing scenario. These findings support the general findings of recent published studies (Lauridsen et al., 2012, Lauridsen et al., 2012a and Lauridsen et al., 2012b) that combination injuries increase the risk of complications.

The choice of treatment offered has a direct effect on the healing outcome. In this study, treatments offered depended on the type of trauma. For those that required root canal dressing; the number of times the dressings were changed was not statistically associated with treatment outcomes. Similarly the condition of the root canal after commencement of dressing was not significantly associated with treatment outcome. The quality of temporary fillings 'in term of stability' and tooth mobility after commencement of dressing were significant factors in determining the treatment outcomes. Further studies are recommended with larger numbers in each trauma category in order to clarify the relevance of these clinical variables.

In this study EADT was significantly associated with treatment outcome. Conversely, EAT and storage medium were not associated with treatment outcome. Only a few cases of dental avulsion were included in this study and this again highlights the need for further larger appropriately designed studies to clarify the effect of these variables on treatment outcome.

5.7 Conclusion

This study is a descriptive retrospective study of only 100 traumatised permanent teeth in a total of 72 patient cases and looked at different variables believed to affect treatment outcomes of traumatized teeth. The number of cases recruited fell short of an estimated power calculation and therefore a generalised conclusion from this part of the research cannot be drawn or extrapolated from such small numbers, but a larger sample size is required. Thus far, and based on this study:

- Dental trauma occurs more frequently in the age group 9-11 years of age
- The most common type of dental trauma was enamel/dentine fracture with pulp exposure
- The most common causes of dental trauma were falls and sporting accidents
- The most frequent locations of dental trauma were houses, schools and streets
- Males were more vulnerable to dental trauma and especially to subsequent trauma
- The success rate of pulpal/endodontic treatment among traumatised anterior permanent teeth was just above 50%. At the same time, short term success was around 35%
- 100% of avulsed teeth require a secondary treatment intervention (RCT)

According to this study, the factors that could have an influence on the treatment outcomes of traumatised teeth are:

- Type of trauma

- Stage of root development
- Quality of temporary filling (in term of stability and leakage)
- Tooth mobility after dressing
- Extra alveolar dry time (for avulsed teeth)

As a result of this study, there is also a great need for:

- Raising, public awareness of dental trauma and the consequences of dental trauma
- Further large studies to evaluate what factors are associated with dental trauma recurrence
- Further studies to recruit larger numbers of cases and then to study each trauma category separately.
- Larger and appropriately designed studies to evaluate the factors affecting treatment outcomes of avulsed teeth

Chapter VI – Dental Avulsion and Treatment Outcomes at a Secondary Referral Centre

6.1 Abstract

Background: Numerous studies have been published to examine the long term variables that might have an effect on treatment outcome of avulsed teeth, but none have been able to estimate the long term prognosis of avulsed and replanted teeth.

Aims: To identify early clinical variables that are most predictive of treatment outcome of avulsed and replanted permanent anterior teeth and to develop a model(s) that will enable prediction of outcomes for future replanted avulsed teeth based on these variables.

Material and Methods: The dental trauma database was used to randomly identify patients who had sustained dental trauma to their permanent anterior teeth leading to avulsion between 1998 and 2007. A data extraction form was designed and completed for each tooth. Demographic, diagnostic and treatment information recorded in the patient's records, in addition to radiographs, were viewed retrospectively and then transcribed and processed. The significance for each early clinical variable was assessed using a univariate logistic regression model. Only significant variables ($P \leq 0.05$) were considered eligible for the prediction model and a c-index was then constructed for their respective predictive power (0.5 = no predictive power, 1.0 = perfect prediction).

Results: Of the original sample of 213 patients who had received treatment for avulsed and replanted teeth between 1998 and 2007 only 105 fulfilled the criteria for evaluation. Two models ('At first visit' and 'at initial treatment visits') were produced with a total of five variables holding the significant univarite association (*P, 0.05*) with the outcome: patient age ($P \leq 0.01$); stage of root formation ($P \leq 0.01$); storage medium ($P = 0.047$); tooth mobility after dressing ($P \leq 0.01$); and tooth mobility after splinting ($P = 0.03$). These variables underwent multivariate analysis and the final models had high predictive abilities (c-index of 0.80 and 0.74).

Conclusion: The early clinical variables that were most predictive of treatment outcome were patient age, stage of root formation, storage medium, tooth mobility after dressing and tooth mobility after splinting. These models enable a clinician to estimate the long term prognosis of avulsed and replanted teeth and will make it easier to plan further treatment with a realistic view of outcome at an early stage.

6.2 Introduction

Dental trauma has both psychological and social impacts on patients and their parents, with consequences that may impair the child's social functioning and emotional stability. In this context, a recent Canadian study showed that trauma to the anterior teeth and especially maxillary incisors had a greater social impact than on functional or psychological development, especially among 12 to 14 year-old children (Fakhruddin et al., 2008). Avulsion injuries are distressing injuries and when the injuries occur they can affect the daily life of both patients and their parents compared to families without any history of trauma (Cortes et al., 2002). Caglayan revealed that dental trauma had the most negative effect on quality of life (Caglayan et al., 2009), this has been confirmed by Aldrigui et al., in 2011. Similarly Gianetti stated that dental avulsion impaired oral health quality of life, especially in patients under 18 years old (Giannetti et al., 2007). This effect on oral health quality of life could be amplified by increasing the number of lost teeth (Steele et al., 2004).

Traumatic avulsion injuries are emergencies that require urgent, appropriate, and immediate treatment, aiming to reduce any suffering in addition to minimizing the chances that any complication might occur (Andreasen et al., 2007, Andersson et al., 2010). Many studies have shown that loss of tooth vitality is frequent sequelae to traumatic avulsion injuries. If pulp necrosis is diagnosed late, severe damage such as root resorption or arrested root formation will occur. On the other hand, endodontic treatment can provide a good chance for long term retention of the avulsed teeth. Therefore, replantation after avulsion should nearly always be attempted even though it might provide only a temporary solution given the frequent occurrence of root resorption. Importantly a resorbing tooth acts as a natural space maintainer preserving the height and the width of the alveolus facilitating later implant placement (Welbury and Gregg 2006), not to mention the positive effects of the treatment (replantation) on the psychological and emotional wellbeing of the patient.

It has been acknowledged for a long time that a replanted tooth following avulsion may function for many years and the healing following replantation has been extensively studied. Andreasen found that, under ideal conditions, complete healing of the pulp and the periodontal ligament can occur after replantation (Andreasen et al., 2007). However, such conditions rarely occur in 'real life', and because of this, replantation of avulsed teeth is often considered as a temporary measure, providing a patient with a natural tooth until its replacement by prosthesis. Despite the vast amount of information reported in the literature, the association between these factors and treatment outcomes remains obscure and is still not clear enough to be able to predict the outcomes of the treatment.

This part of the research aims to identify and to determine the early clinical variables that were most predictive of treatment failure of replanted avulsed teeth referred to a secondary referral centre (Glasgow Dental Hospital and School – GDHS) and to develop models that would predict the failure for replanted avulsed teeth based on these early clinical variables. Section 6.3 of this chapter will cover the aims and objectives of this study. Methods adopted to achieve these aims and objectives will be presented in Section 6.4 and the results in Section 6.5. The discussion and conclusion of this study will be presented in Sections 6.6 and 6.7.

6.3 Aims and Objectives

The aims of this part of the research were to:

- Determine the early factors associated with the development of clinical consequences of avulsed teeth
- Identify and determine the early biological and treatment associated variables that are most predictive of treatment outcomes in avulsed teeth
- To apply contemporary statistical methods to determine the magnitude of these variables on the outcomes

6.4 Methods

The study consisted of two parts in order to fulfil the aims and objectives of this part of research. The first part was a review of patients' records gathering the target data together with an assessment of each radiograph taken throughout the follow-up period. The second part was a review of all related variables. These were subsequently pooled together to develop models that would predict the outcomes for replanted avulsed teeth based on the early clinical variables. The study outcomes were categorized into two groups either 'failure' or 'functional success' according to the outcomes assessment criteria. These are simple criteria based upon every clinician's 'goal'; namely to retain an avulsed and reimplanted tooth functioning in the mouth either until or after growth of the facial skeleton has ceased. Therefore, our definition of 'functional success' of an avulsed tooth is that it is retained in the mouth until craniofacial growth and development are completed. Success does not therefore necessarily require the tooth to be healthy and functioning for the entire life of the patient. This philosophy in the growing patient has been reported by other authors in this field (McIntyre et al., 2007, Trope 2011).

6.4.1 Study sample

The study population comprised patients treated within the Paediatric Department of Glasgow Dental Hospital and School (GDHS), who had sustained traumatic injuries leading to avulsion of anterior permanent tooth/teeth. The department trauma database was used to identify all patients who had received treatment for dental avulsion in the period 1998 to 2007. An attempt was made to recruit all the cases that met the inclusion criteria (Table 6.1) to participate in the study. For each patient only one replanted avulsed tooth was randomly selected to be recruited in the study. Avulsed teeth that were not replanted, cases that did not return for treatment, cases with root fracture, autotransplantation cases, and cases who had sustained subsequent trauma after replantation were all excluded from the study.

Table 6.1 Inclusion criteria

Type of trauma	Avulsion (replanted avulsed teeth)
Number of teeth/patient	One tooth/patient
Follow-up	Complete follow up

6.4.2 Data elements

Diagnostic and treatment information recorded in the patient’s record and on the formatted structured history trauma sheet in the records, in addition to radiographs, were the source of the data for this study. In order to aggregate all the target information from the patients’ records, an extraction data form (Appendix 4) was designed to include all the early variables believed to affect the treatment outcomes including the patient's demographics as well as clinical and radiographic information. For each tooth, an extraction data form was completed and given a unique ID number and coded for computer entry. Confidentiality of patient information was considered throughout the study, as each patient’s name and contact details were kept concealed.

6.4.3 Radiographic evaluation

Each tooth was evaluated for the presence of any radiographically detectible pathological changes, including root resorption, on a standard viewing box. Subsequently, each set of radiographs for each patient was analysed according to the chronological order of the visits until the pathological changes were detected. Andersson’s root resorption index (Andersson et al., 1989) was used to describe the progress of root resorption. Samples of radiographs were reviewed randomly by a senior consultant under standardised conditions. In these cases a final agreement was reached. Each radiograph was analysed till the tooth had either been retained or lost.

6.4.4 Statistical analysis

After discussion and consultation with the statistician, SPSS statistical software programme 15.0 Standard version was adopted for use in data analysis. The data were subsequently coded, entered, processed and then analysed. One tooth per patient was studied. The outcome of interest of this study was 'failure of treatment'. Each variable in the study was examined first of all by frequency tabulation; frequencies were presented as raw numbers and as percentages. At the same time variables were pooled into categories that tried to represent natural grouping, attempting to retain reasonable numbers of subjects in each category. The results for each variable were then expressed in the form of Pearson's chi-square (x^2) test and odds ratios (OR) with 95% confidence intervals. Relative risk estimates related to the final outcome were calculated for variables with a significant effect on the outcome.

In order to assess the individual predictive power for each variable a univariate logistic regression model was employed. Only those variables that were significant at the 5% level were considered for further assessment. The comparison of sensitivity with specificity was assessed for each variable using the receiver operating characteristic (ROC) curve (Harrell et al., 1984, Harrell et al., 1996), which permits evaluation of the predictive power for each variable by comparing the area under the ROC curve using c-index. This reduced the dimensions of the study variables.

	Outcome Positive	Outcome Negative
Variable Positive	A	B
Variable Negative	C	D

Sensitivity = A/(A+C), Specificity = D/(B+D)

The c-index is equal to the area under the receiver operating characteristic (ROC) curve (Harrell et al., 1984, Harrell et al., 1996). Generally the area under the curve ranges from 0.5 to 1.0 and provides a measure of the model's ability to discriminate between those subjects who experience the outcome of interest versus those who do not (Altman and Bland 1994, Hosmer and

Lemeshow, 2000). A variable with no predictive power (no discrimination) has a c-index of 0.5 and a variable with perfect predictive power (excellent discrimination) has a c-index of 1. As a general rule Hosmer and Lemeshow suggests:

If $ROC = 0.5$: this suggests no discrimination
If $0.7 \leq ROC < 0.8$: this is considered acceptable discrimination
If $0.8 \leq ROC < 0.9$: this is considered excellent discrimination
If $ROC \geq 0.9$: this is considered outstanding discrimination

The early clinical variables that were identified as significant in this analysis were then analysed once more using forward stepwise logistic regression to produce a model that can predict treatment outcome. Given the nature and specificity of this type of trauma and its treatment, these variables were pooled together to form two groups based on the consequences of the variable in the process (variables 'at first visit' stage and variables 'at initial treatment visits' stage). Hence, two models were produced that could predict the treatment outcome: *Model 1-* 'At first visit'; *Model 2-* 'At initial treatment visits'. All cases (teeth) were included in this analysis apart from those omitted because of a missing subject data point, regardless of the availability of the others.

6.5 Results

6.5.1 Data generated and its description

A total of 213 patients' records were studied. 108 were excluded at the beginning of the study owing to; tooth loss at the time of the accident (not re-implanted); patient failed to return for treatment; cases with concomitant root fracture (complicated trauma); autotransplantation cases; cases had sustained subsequent trauma (second trauma on the same tooth). One hundred and five avulsed permanent teeth in 105 patients were subsequently recruited. There were no decoronation cases in the sample. All patients were regular attenders to GDHS in the period between 1998 and 2007; among them 57.1% (60) were males and 42.9% (45) were females. The mean of patients ages at time of trauma was 10 years (SD 2.61yrs), with a range of between 6 - 16 years. Avulsion trauma was most frequent in age group 6 – 9 years of age (Figure 6.1).

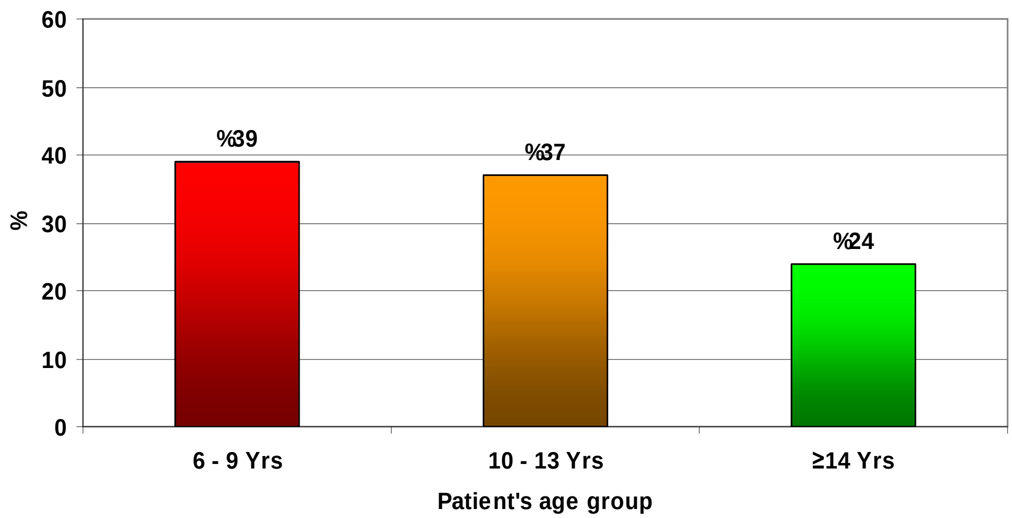


Figure 6.1 Dental avulsion by patient's age

The most commonly traumatised teeth were the upper right and left central incisors 61.9% and 29.5% respectively while the lower teeth were less commonly traumatised (Table 6.2).

Table 6.2 Frequency of avulsed teeth by tooth ID

Tooth identification	Frequency	%
Upper Rt central incisor	65	61.9
Upper Rt lateral incisor	3	2.9
Upper Lt central incisor	31	29.5
Upper Lt lateral incisor	2	1.9
Lower Lt central incisor	1	1.0
Lower Lt lateral incisor	1	1.0
Lower Rt lateral incisor	2	1.9
Total	105	100.0

The injury mechanisms in this study were varied. Sporting accidents (44.8%) and falls (40%), were the most common causes of dental avulsion (Table 6.3). In addition the locations at which these injuries occurred were varied too. Apart from unspecified (18%) the most frequent locations were outdoors (64%) and at school (18%) (Table 6. 4).

Table 6.3 Dental avulsion by injury mechanism

Cause	Frequency	%
Falls	42	40.0
Sports Accident	47	44.8
Others	16	15.2
Total	105	100.0

Table 6.4 Dental avulsion by location

Location	Frequency	%
Outdoor	67	63.8
School	19	18.1
Others	19	18.1
Total	105	100.0

At the time of trauma some patients sustained a complicated trauma comprising avulsion either with enamel dentine fracture or with pulp exposure (16.2%, n=17). However the majority (83.8%, n=88) of recruited cases were avulsion only (Table 6.5). The number of avulsed teeth in the same patient at the same accident was varied. Some 63 cases (60%) suffered trauma on a single tooth and 40% (42) had two or more avulsed teeth at the same occasion (Table 6.6).

Table 6.5 Trauma description

Trauma description	Frequency	%
Avulsion	88	83.8
Avulsion + crown # (E#, ED# or EDP).	17	16.2
Total	105	100.0

Table 6.6 Number of avulsed teeth at same occasion

	Frequency	%
One	63	60.0
Two or more	42	40.0
Total	105	100.0

The mean follow-up period for each case was about 4 years (SD 2.16yrs), ranging between 0.19 and 10.82 years (Table 6.7). At the same time, the number of visits to the dental hospital (GDHS) since the accident was counted; 24 visits was the mean and 60 visits the maximum (Table 6. 8). For these cases the distance from home to GDHS was documented and is shown in Table 6.9.

Table 6.7 Duration of follow-up (yrs)

	Valid	105
	Missing	0
Mean		3.8747
Std. Deviation		2.16017
Minimum		.19
Maximum		10.82

Table 6.8 Number of visits (since trauma)

	Valid	104
	Missing	1
Mean		23.9423
Std. Deviation		10.0955
Minimum		9.00
Maximum		60.00

Table 6.9 Distance to GDHS (miles)

	Valid	105
	Missing	0
Mean		17.142
Std. Deviation		16.029
Minimum		1.3
Maximum		98.4

Extra alveolar dry time (EADT) for each recruited tooth was counted and recorded. The range was between 0 – 420 min with a mean of 41 min (Table 6.10). EADT was less than 60 min for 67.6% (71) of the recorded cases (Table 6.11).

Table 6.10 EADT (min)

	Valid	82
	Missing	23
Mean		40.96
Std. Deviation		69.05
Minimum		0
Maximum		420

Table 6.11 EADT/min (frequency)

		Frequency	%
Valid	0.0 - 60min	71	67.6
	>60min	11	10.5
	Total	82	78.1
Not specified		23	21.9
	Total	105	100.0

The type of storage medium was varied. The majority of the cases (70%, n=73) were stored in milk, whilst the remainder were stored either dry or in other media (Table 6.12).

Table 6.12 Storage medium

	Frequency	%
Milk	73	69.5
Dry	16	15.2
Others	16	15.2
Total	105	99.9.0

48 (46%) teeth had completely formed roots, 36% had nearly completed roots and the remainder (18%) were immature rooted teeth at the time of their presentation after the avulsion (Table 6.13).

Table 6.13 Stage of root formation at trauma time

	Frequency	%
Immature	19	18.1
Nearly complete	38	36.2
Complete	48	45.7
Total	105	100.0

The type of tooth fixation (splinting) was documented for the recruited teeth. The most common type of splint was composite/wire (70%, n=73) (Table 6.14). In all, the fixation period for about 46% of the cases (43) was less than 10 days and between 11-15 days for about 23% of the cases (22) (Table 6.15). Mobility after splinting was recorded in 60% of cases (58) (Table 6.16).

Table 6.14 Type of splint

	Frequency	%
None	8	7.6
Composite/wire	73	69.5
Others	24	22.9
Total	105	100.0

Table 6.15 Splinting period

		Frequency	%	Valid %
Valid	0 -10days	43	41.0	45.7
	11 - 15days	22	21.0	23.4
	>16 days	29	27.6	30.9
	Total	94	89.6	100.0
Not specified		11	10.5	
Total		105	100.0	

Table 6.16 Mobility after splinting

		Frequency	%	Valid %
Valid	No	39	37.1	40.2
	Yes	58	55.2	59.8
	Total	97	92.3	100.0
No splint cases		8	7.6	
Total		105	100.0	

Forty-eight cases (46%) had their pulp removed within 15 days and only 4 cases (4%) did not require pulpal removal as they revascularised (Table 6.17). Non-setting calcium hydroxide (NS-$Ca(OH)_2$) was the most popular initial intra canal dressing used (85%) compared to only 15% of cases that were initially dressed with Ledermix then by (NS-$Ca(OH)_2$) (Table 6.18). The frequency and the number of times the root canal dressings were changed depended on both the stage of root formation and the dryness of the root canal. Teeth with incompletely developed roots and teeth with canals which failed to dry required longer total durations of intra canal dressings and more changes of dressings.

Table 6.17 Time elapse until pulp access

		Frequency	%	Valid %
Valid	0 -15 days	48	45.7	47.5
	16-30 days	18	17.1	17.8
	> 30days	35	33.3	34.7
	Total	101	96.1	100.0
Not specified		4	3.8	(Not RCT cases)
Total		105	100.0	

Table 6.18 Type of canal dressing (s) used

	Frequency	%	Valid %
NS-$Ca(HO)_2$	85	81.0	85.0
Ledermix then NS-$Ca(HO)_2$	15	14.3	15.0
Total	100	95.3	100.0
Not specified	5	4.8	
Total	105	100.0	

Some 13.9% of accessed root canals had either pus or other signs of infection after start of root canal dressing (Table 6.19). Mobility after commencement of root canal dressing was documented in 51% of cases (Table 6.20).

Table 6.19 Root canal after dressing

	Frequency	%	Valid %
Dry and clean	87	82.9	86.1
Pus (or any sign of infection)	14	13.3	13.9
Total	101	96.2	100.0
Not specified	4	3.8	
Total	105	100.0	

Table 6.20 Mobility after dressing

		Frequency	%	Valid %
Valid	No	49	46.7	48.5
	Yes	52	49.5	51.5
	Total	101	96.2	100.0
Not specified		4	3.8	
Total		105	100.0	

Root resorption is one of the most common treatment complications after dental trauma especially dental avulsion, and it always determines the prognosis of the treatment. Root resorption was observed in 81 cases (77%) and in more than 58 cases (55%) the type was inflammatory root resorption. Replacement root resorption was observed in only 23 cases (22%) (Table 6.21). Some 62 cases (59%) showed progressive root resorption (Table 6.22).

Table 6.21 Type of root resorption

	Frequency	%
None	24	22.9
Inflammatory	58	55.2
Replacement	23	21.9
Total	105	100.0

Table 6.22 Progressive root resorption

	Frequency	%
Yes	62	59.0
No	43	41.0
Total	105	100.0

6.5.2 Effects of main study variables on treatment outcomes

In order to enable assessment of treatment outcomes some guidelines and criteria were established. Each tooth was classified according to this criteria into ‘Functional success’ or ‘Failure’ (Table 6.23).

Table 6.23 Criteria for treatment outcome assessment

Outcome	Criteria
Functional success	A tooth is still in the mouth with normal tooth function A tooth is retained with no clinical signs of infection up to the age of full growth Tooth extracted after achievement of full growth and long term treatment (Implant/Prosthesis) already started
Failure	Tooth extracted before achieving full growth Tooth is still in the patients mouth with presence of clinical signs of infection and expected to be extracted before the age of full growth

Based on the study assessment criteria (Table 6.23), the failure rate was 34% (36 cases), while functionally successful treatment was recorded in 66% (69 cases)(Table 6. 24 and Figure 6.2).

Table 6.24 Treatment outcomes

	Frequency	%
Functional success	69	65.7
Failure	36	34.3
Total	105	100.0

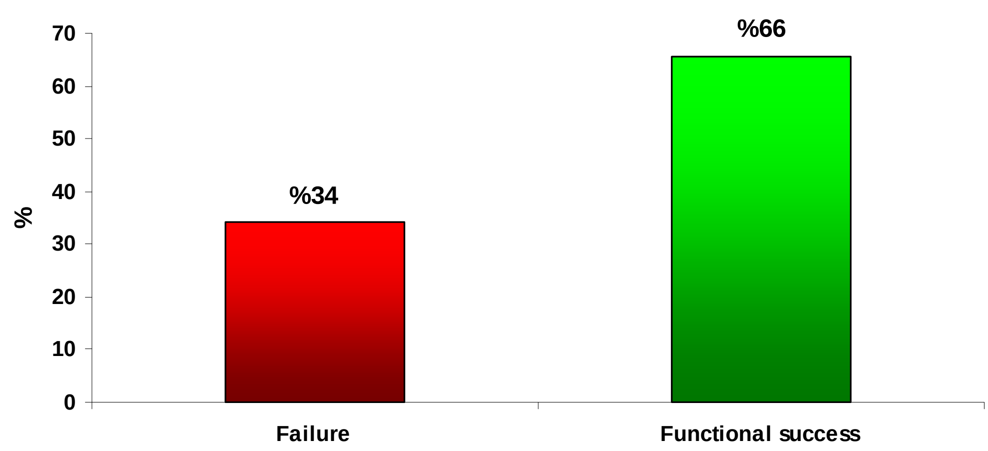


Figure 6.2 Treatment outcomes

6.5.2.1 Effect of patient's age at trauma time on treatment outcomes

The age of the patient at the time of accident had a significant effect on treatment outcomes. Failure was more common in younger age patients than in the older ages (n=105, $P \leq 0.001$) (Table 6.25).

Table 6.25 Patient's age and treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
6 -9 yrs old		24	17	41
	%	58.5%	41.5%	100.0%
10 -13 yrs old		11	28	39
	%	28.2%	71.8%	100.0%
≥14 yrs old		1	24	25
	%	4.0%	96.0%	100.0%
Total		36	69	105
	%	34.3%	65.7%	100.0%

P value ≤ 0.001 (Pearson Chi-Square Test)

6.5.2.2 Effect of stage of root formation on treatment outcomes

Table 6.26 and Figure 6.3 show the significant association between the stage of root formation and the treatment outcomes. The teeth with completely formed roots had a greater success rate (87.5%) compared to the teeth with developing roots (47.4%). Some 60.9 % of successful cases were teeth with completely formed roots (n=105, $P \leq 0.001$).

Table 6.26 Effect of stage of root formation on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
Immature		10	9	19
	%	52.6%	47.4%	100.0%
	% within final outcomes	27.8%	13.0%	18.1%
Nearly complete		20	18	38
	%	52.6%	47.4%	100.0%
	% within final outcomes	55.6%	26.1%	36.2%
Complete		6	42	48
	%	12.5%	87.5%	100.0%
	% within final outcomes	16.7%	60.9%	45.7%
Total		36	69	105
	%	34.3%	65.7%	100.0%
	% within final outcomes	100.0%	100.0%	100.0%

P value≤ 0.001 (Pearson Chi-Square Test)

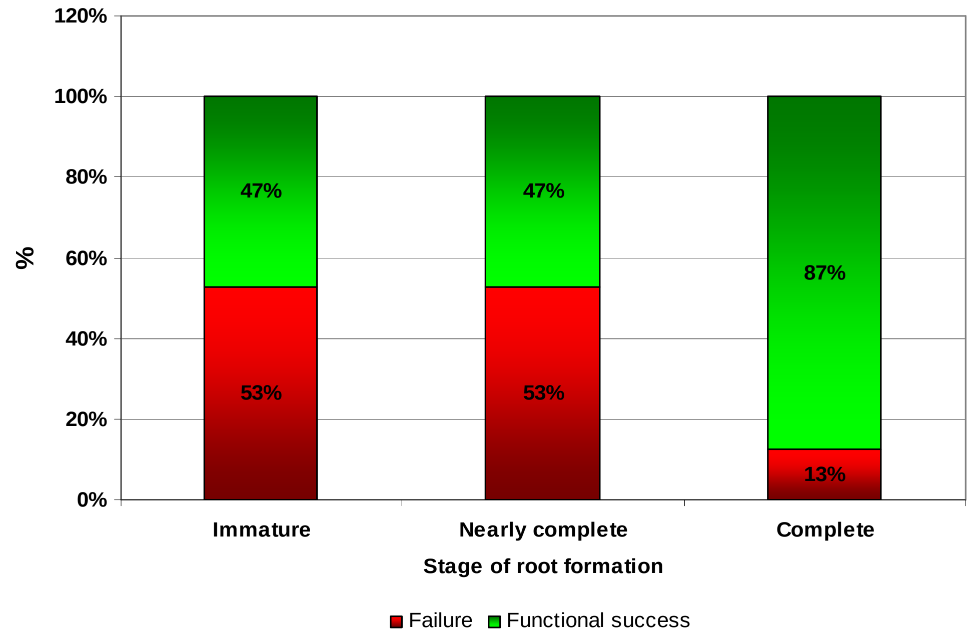


Figure 6.3 Effect of stage of root formation on treatment outcomes

6.5.2.3 Effect of additional coronal trauma on treatment outcomes

Treatment outcomes were not significantly associated with complexity of trauma (*P= 0.513*) (Table 6.27). However, in cases where the coronal pulp remained intact and was not involved (avulsion only), the failure rate was less than in more severe cases (with E#, ED# or EDP#) (Table 6.27).

Table 6.27 Effect of additional coronal trauma on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
Avulsion only		29	59	88
	%	33.0%	67.0%	100.0%
Avulsion + (E#/ED#/EDP#)		7	10	17
	%	41.2%	58.8%	100.0%
Total		36	69	105
	%	34.3%	65.7%	100.0%

P value =0.513 (Pearson Chi-Square Test)

6.5.2.4 Effect of extra alveolar dry time (EADT) on treatment outcomes

The Extra Alveolar Dry Time (EADT) was studied to identify any association with treatment outcomes. For 23 (22%) cases the EADT was unknown. Statistical analysis among studied cases shows that EADT was not significantly associated with the outcomes of the treatment (n= 82, *P = 0.065*) (Table 6.28). However the majority of successful cases had a short EADT (Table 6.28 and Figure 6.4).

Table 6.28 Effect of EADT on treatment outcomes

			Treatment outcomes		Total
			Failure	Functional success	
EADT	< 5 min		3	19	22
		%	13.6%	86.4%	100.0%
	5 -15 min		5	7	12
		%	41.7%	58.3%	100.0%
	16 - 30 min		10	15	25
		%	40.0%	60.0%	100.0%
	31 -60 min		5	7	12
		%	41.7%	58.3%	100.0%
	> 60 min		7	4	11
		%	63.6%	36.4%	100.0%
Total			30	52	82
		%	36.6%	63.4%	100.0%

P value =0.065 (Pearson Chi-Square Test).

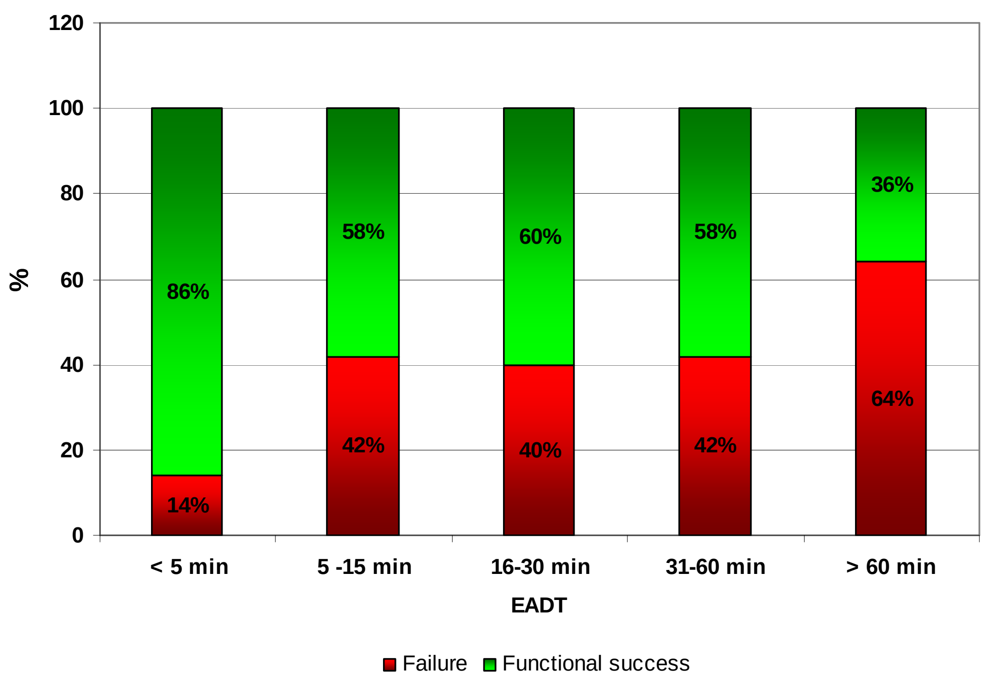


Figure 6.4 Effect of EADT on treatment outcomes

6.5.2.5 Effect of storage medium on treatment outcomes

The analysis shows that dry storage medium was significantly associated with treatment failure (n= 105, P = *0.047*) (Table 6.29 and Figure 6.5).

Table 6.29 Effect of storage medium on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
Milk		21	52	73
	%	28.8%	71.2%	100.0%
Dry		10	6	16
	%	62.5%	37.5%	100.0%
Others		5	11	16
	%	31.3%	68.8%	100.0%
Total		36	69	100
	%	34.3%	65.7%	100.0%

P value =0.047 (Pearson Chi-Square Test)

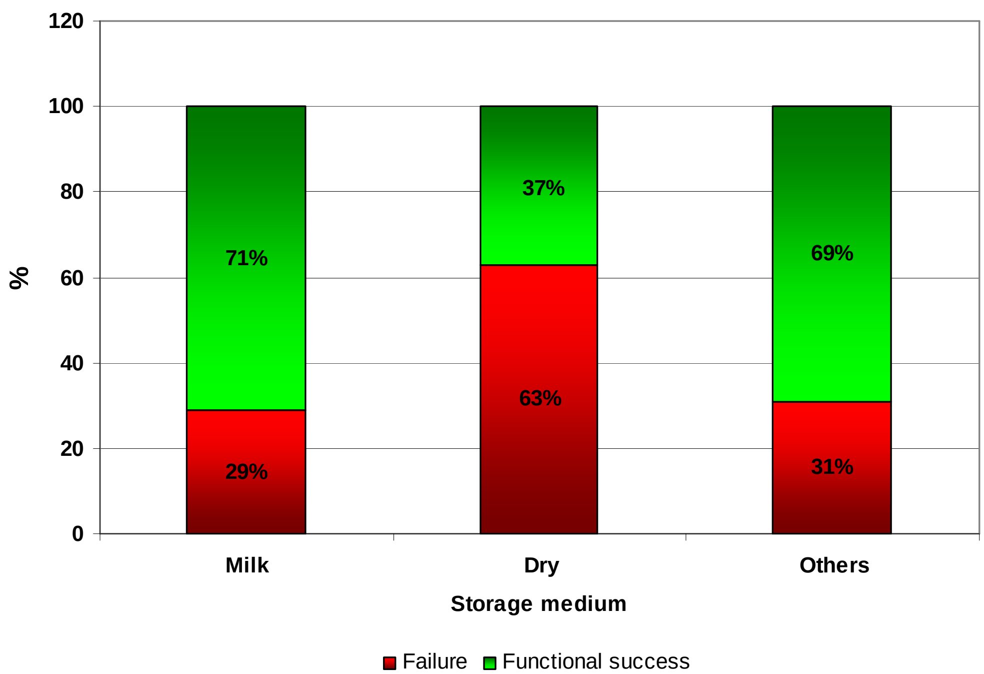


Figure 6.5 Effect of storage medium on treatment outcomes

6.5.2.6 Effect of use of antibiotics on treatment outcomes

Antibiotics were prescribed for more than a half of the cases n= 57 (54.3%). However there was no statistically significant association with success compared to those cases which were treated without any antibiotics (n=105, *P = 0.850*) (Table 6.30).

Table 6.30 Effect of use of antibiotics on treatment outcomes

			Treatment outcomes		Total
			Failure	Functional success	
	No		16	32	48
		%	33.3%	66.7%	100.0%
	Yes		20	37	57
		%	35.1%	64.9%	100.0%
Total			36	69	100
		%	34.3%	65.7%	100.0%

P value =0.850 (Pearson Chi-Square Test).

6.5.2.7 Effect of root surface contamination on treatment outcomes

Based on this study, there was no statistically significant association between contamination of the avulsed tooth and final outcome (*P = 0.290*) (Table 6.31).

Table 6.31 Effect of root surface contamination on treatment outcomes

			Treatment outcomes		Total
			Failure	Functional success	
	Not cited		9	27	36
		%	25.0%	75.0%	100.0%
	Washed off		26	39	65
		%	40.0%	60.0%	100.0%
	Not completely clean		1	3	4
		%	25.0%	75.0%	100.0%
Total			36	69	100
		%	34.3%	65.7%	100.0%

P value =0.290 (Pearson Chi-Square Test)

6.5.2.8 Effect of splinting time on treatment outcomes

The splinting time (fixation period) was recorded for 94 cases. Splinting time had no statistically significant association with outcomes (*P = 0.902*) (Table 6.32).

Table 6.32 Effect of splinting time on treatment outcomes

Splinting period		Treatment outcomes: Failure	Treatment outcomes: Functional success	Total
0 -10days		15	28	43
	%	34.9%	65.1%	100.0%
11 - 15days		7	15	22
	%	31.8%	68.2%	100.0%
>15 days		11	18	29
	%	37.9%	62.1%	100.0%
Total		33	61	94
	%	35.1%	64.9%	100.0%

P value =0.902 (Pearson Chi-Square Test)

6.5.2.9 Effect of tooth mobility after splinting on treatment outcomes

There was a statistically significant association between tooth mobility after splinting and treatment outcomes (n= 97, *p=0.002*) (Table 6.33).

Table 6.33 Effect of tooth mobility after splinting on treatment outcomes

Mobility after splinting		Treatment outcomes: Failure	Treatment outcomes: Functional success	Total
No		7	32	39
	%	17.9%	82.1%	100.0%
Yes		28	30	58
	%	48.3%	51.7%	100.0%
Total		35	62	97
	%	36.1%	63.9%	100.0%

P value =0.002 (Pearson Chi-Square Test)

6.5.2.10 Effects of time elapsed until pulp access and type of root dressing on treatment outcomes

The analysis did not demonstrate any significant statistical association between time elapsed until pulp access and treatment outcomes (n= 101, *P = 0.412*). However, 52.3% of successful cases were recorded among those teeth which were accessed within a short period of time (<15 days) (Table 6.34 and Figure 6.6). Similarly there was no statistical association between type of root canal dressing and final outcome (n= 100, *P =0.463*) (Table 6.35).

Table 6.34 Effect of time elapsed until pulpal access on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
0 -15 days		14	34	48
	%	29.2%	70.8%	100.0%
	% within final outcomes	38.9%	52.3%	47.5%
16-30 days		8	10	18
	%	44.4%	55.6%	100.0%
	% within final outcomes	22.2%	15.4%	17.8%
> 30days		14	21	35
	%	40.0%	60.0%	100.0%
	% within final outcomes	38.9%	32.3%	34.7%
Total		36	65	101
	%	35.6%	64.4%	100.0%
	% within final outcomes	100.0%	100.0%	100.0%

P value =0.412 (Pearson Chi-Square Test)

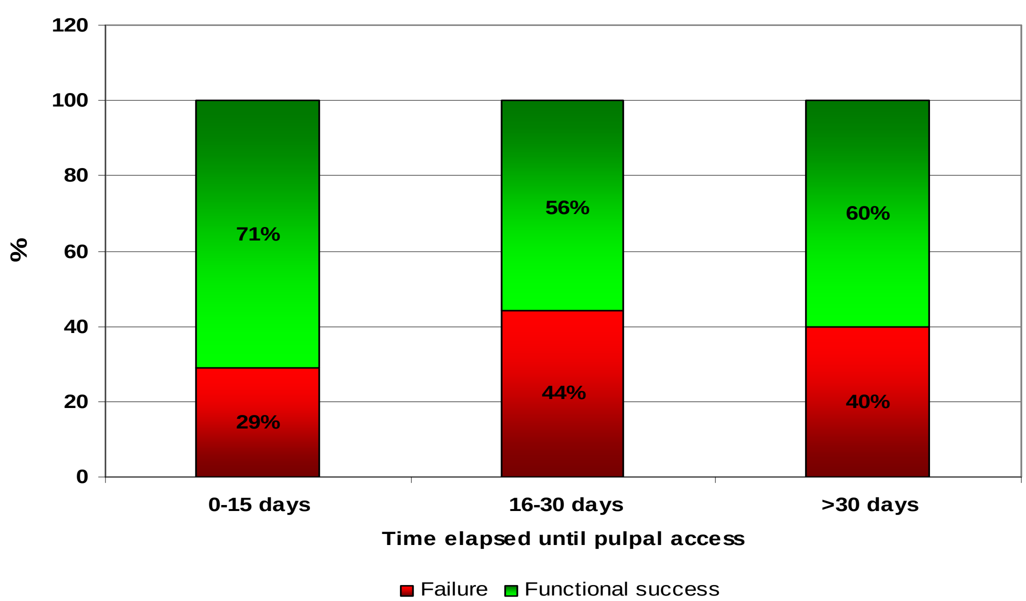


Figure 6.6 Effect of time elapsed until pulpal access on treatment outcomes

Table 6.35 Effect of dressing type on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
$NS\text{-}Ca(HO)_2$		31	54	85
	%	36.5%	63.5%	100.0%
Ledermix then $NS\text{-}Ca(HO)_2$		4	11	15
	%	26.7%	73.3%	100.0%
Total		35	65	100
	%	35.0%	65.0%	100.0%

P value =0.463 (Pearson Chi-Square Test)

6.5.2.11 Effect of tooth mobility after dressing on treatment outcomes

There was a statistically significant association between tooth mobility after the commencement of dressing and the final outcome (n= 101, $P \leq 0.001$) as shown in Table 6.36.

Table 6.36 Effect of tooth mobility after dressing on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
No		8	41	49
	%	16.3%	83.7%	100.0%
Yes		28	24	58
	%	53.8%	46.2%	100.0%
Total		36	65	101
	%	36.0%	64.0%	100.0%

P value ≤ 0.001 (Pearson Chi-Square Test)

6.5.2.12 Effect of root canal condition after dressing on treatment outcomes

101 out of 105 cases (96.2%) required root canal intervention either as a conventional root canal treatment or an apexification procedure. The condition of the root canal after starting the process of canal dressing was considered in order to find out if there was any association between the condition of the root canal and the treatment outcome. 87% of recruited cases were reported as having dry and clean canals. Table 6.37 shows that there was no statistical association between the condition of the root canal and the treatment outcomes (n=101, *P =0.580*). However descriptively a lower failure rate was observed among cases reported as dry and clean (36%), compared to those reported with pus or any sign of infection where the failure rate was 43%.

Table 6.37 Effect of root canal condition after dressing on treatment outcomes

		Treatment outcomes		Total
		Failure	Functional success	
Dry and clean		30	57	87
	%	34.5%	65.5%	100.0%
Pus (or any sign of infection)		6	8	14
	%	42.9%	57.1%	100.0%
Total		36	65	101
	%	35.6%	64.4%	100.0%

P value =0.580 (Pearson Chi-Square Test)

6.5.3 Models production

The significance of all the variables in terms of P value and their predictive ability in terms of c- index (using univariate logistic regressions) are summarized in Table 6.38 in descending order of significance.

Table 6.38 Univariate analysis of prognostic variables

Variable	Outcomes F-Success (%)	Outcomes Failure (%)	*OR (95%CI)*	*P value*	C-index
Age at trauma (age group)				0.001	0.80
6 -9 yrs old	17(41.5)	24 (58.5)	1		
10 -13 yrs old	28 (71.8)	11(28.2)	0.28 (0.11 - 0.71)		
≥14 yrs old	24 (96.0)	1(4.0)	0.03 (0.01 - 0.24)		
Stage of root formation				0.001	0.76
Immature	9(47.4)	10(52.6)	1		
Nearly complete	18(47.4)	20(52.6)	1 (0.33 - 3.01)		
Complete	42(87.5)	6(12.5)	0.13 (0.04 - 0.45)		
Tooth mobility after dressing				0.001	0.70
No	41 (83.7)	8 (16.3)	1		
Yes	24 (46.2)	28 (53.8)	5.98 (2.35 - 15.21)		
Tooth mobility after splinting				0.003	0.70
No	32 (82.1)	7 (17.9)	1		
Yes	30 (51.7)	28 (48.3)	4.27 (1.62 - 11.22)		
Storage medium				0.047	0.58
Milk	52(71.2)	21(28.8)	1		
Dry	6(37.5)	10(62.5)	4.13 (1.33 - 12.80)		
Others	11(68.8)	5(31.3)	1.13 (0.35 - 3.64)		
Number of injured teeth				0.068	0.58
One	37(58.7)	26(41.3)	1		
Two or more	32(76.2)	10(23.8)	0.45 (0.19 - 1.06)		
EADT				0.102	0,67
<5 min	19(86.4)	3(13.6)	1		
5 -15 min	7(58.3)	5(41.7)	4.52 (0.85 - 24.11)		
16 - 30 min	15(60.0)	10(40.0)	4.22 (0.98 - 18.13)		
31 -60 min	7(58.3)	5(41.7)	4.52 (0.85 - 24.11)		
> 60 min	4(36.4)	7(63.6)	11.10 (1.97 - 62.51)		
Contamination				0.296	0.52
Not cited	27(75.0)	9(25.0)	1		
Washed off	39(60.0)	26(40.0)	2 (0.81 - 4. 93)		
Not completely clean	3(75.0)	1(25.0)	1 (0.92 - 10.87)		
Trauma location				0.368	0.54
Outdoor	45(67.2)	22(32.8)	1		
School	14(73.7)	5(26.3)	0.73 (0.23 -2.29)		
Others	10(52.6)	9(47.4)	1.84 (0.65 - 5.18)		
Time to pulp access				0.415	0.60
1 -15 days	34(70.8)	14(29.2)	1		
16-30 days	10(55.6)	8(44.4)	1.94 (0.64 - 5.95)		
>30 days	21(60.0)	14(40.0)	1.62 (0.65 - 4 .06)		
Main cause of trauma				0.452	0.54
Fall	29(69.0)	13(31.0)	1		
Sport Accident	28(59.6	19(40.4)	1.51 (0.63 - 3.64)		
Others	12(75.0)	4(25.0)	0.74 (0.20 - 2.75)		
Type of root dressing				0.466	0.51
NS-Ca(HO)2	54(63.5)	31(36.5)	1		
Ledermix then NS-Ca(HO)2	11(73.3)	4(26.7)	0.63 (0.19 - 2.16)		
Tooth ID				0.487	0.58
Upper Rt central incisor	40(61.5)	25(38.5)	1		
Upper Lt central incisor	22(71.0)	9(29.0)	0.66 (0.26 - 1.65)		
Others	7(77.8)	2(22.2)	0.46 (0.09 - 2.34)		
Additional coronal trauma				0.515	0.51
Avulsion only	59(67.0)	29(33.0)	1		
Avulsion + crown fracture	10(58.8)	7(41.2)	1.42 (0.49 - 4.12)		
Root canal after dressing				0.545	0.55
Dry and clean	57(65.5)	30(34.5)	1		
Pus (or any sing of infection	8(57.1)	6(42.9)	1.43 (0.45 - 4.49)		
Use of antibiotics				0.850	0.55
No	32(66.7)	16(33.3)	1		
Yes	37(64.9)	20(35.1)	1.08 (.05 - 2.43)		
Splinting time				0.902	0.51
0 -10days	28(65.1)	15(34.9)	1		
11 - 15days	15(68.2)	7(31.8)	0.87 (0.29 - 2.60)		
>16 days	18(62.1)	11(37.9)	1.14 (0.43 - 3.03)		

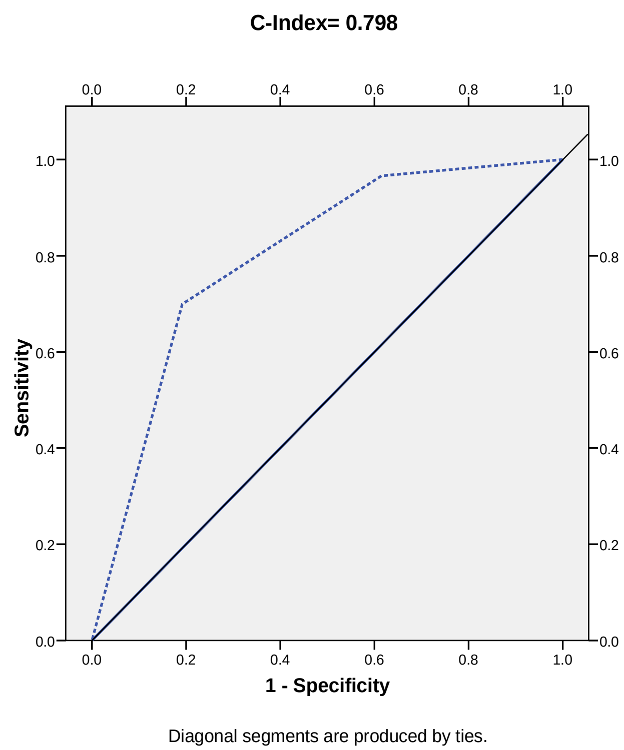
Overall 82 of 105 subjects (teeth) were entered into the final stage of analysis (model production process). Twenty-three teeth were omitted from the analysis because of missing data points in certain variables regardless of the availability of the others.

6.5.3.1Model 1

This model enables prediction of the outcome at the first visit after trauma. Combinations of significant variables were selected and entered into the model: Patient age 'Age group'; Storage medium; and Stage of root formation.

	P value	*C- index*
Patient age (Age group)	0.001	0.80
Storage medium	0.047	0.58
Stage of root formation	0.001	0.76

These three variables were entered together into one model which showed a good predictive ability (*c-index* of 0.80) (Figure 6.7). The overall accuracy of the model to predict failure of the treatment was 76.8% (Figure 6.7). The major factors influencing the outcome (treatment failure) at this early stage (at first visit) after trauma would appear to be: younger age; dry storage medium; and immature roots.



Model 1 predicted probability (area under the curve)

Test Result Variable(s): Predicted probability

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.798	.050	.000	.700	.896

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Model 1: Classification table

Observed			Predicted		
			OUTCOME		Percentage Correct
			F-Success	Failure	
Step 1	OUTCOME	Success	42	10	80.8
		Failure	9	21	70.0
	Overall Percentage				76.8

Figure 6.7 Model 1 results

6.5.3.2 Model 2

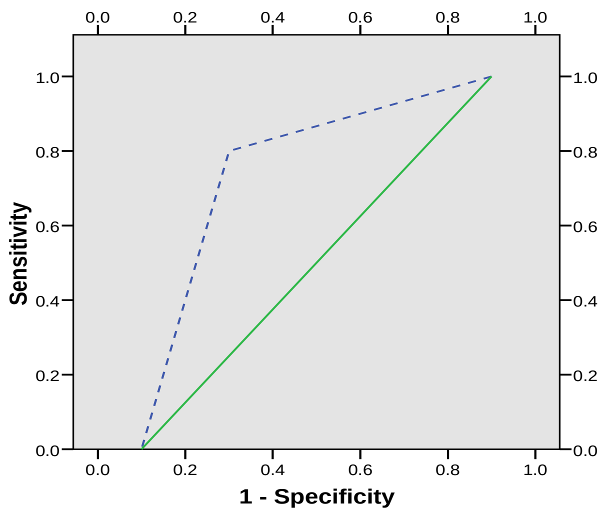
This model enables prediction of long term outcome from early clinical information collected at initial treatment visits (10 to 45 days after trauma). Combinations of significant variables were selected and entered into this model: tooth mobility after dressing; and tooth mobility after splinting.

	P value	*C- index*
Tooth mobility after dressing	**≤ 0.001**	**0.70**
Tooth mobility after splinting	**0.003**	**0.70**

These two variables were entered together into the model and showed good predictive ability (*c-index* of 0.74) (Figure 6.8). The overall accuracy of the model to predict failure of treatment was 72% (Figure 6.8).

The major factors influencing the outcome (treatment failure) at this stage of ‘initial treatment visits’ after dental avulsion and replantation appear to be the recording of tooth mobility, either after splinting or after commencement of root canal dressing.

C- index=0.737



Diagonal segments are produced by ties.

Model 2 predicted probability (area under the curve)

Test Result Variable(s): Predicted probability

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.737	.057	.000	.624	.849

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Model 2: Classification table

Observed			Predicted		
			OUTCOME		Percentage Correct
			F-Success	Failure	
Step 1	OUTCOME	Success	35	17	67.3
		Failure	6	24	80.0
	Overall Percentage				72.0

Figure 6.8 Model 2 results

6.6 Discussion

The main observations emanating from this study were the magnitude of risk that dry storage medium, immature roots and a younger age exerts on the outcome (treatment failure) at an early stage after dental avulsion and replantation (first visit after trauma), and the magnitude of risk that the recording of tooth mobility, either after splinting or after commencement of root canal dressing exerts on the outcome at ‘initial treatment visits’ after avulsion (10 to 45 days after trauma). This is the first study to have looked at the effects of clinical variables on the outcome of avulsed and replanted teeth and to have developed a prediction model to predict prognosis. Two models were produced from the five variables holding the greatest predictive power (c-index) which underwent multivariate analysis. The final models were developed with high predictive abilities ‘c-index’ of 0.80 and 0.74 (c-index of 1.0 being perfect prediction [Hosmer and Lemeshow, 2000]), with an overall prediction accuracy of 77% and 72% correspondingly. These levels of prediction abilities and prediction accuracy validate the models and their abilities to predict treatment outcome (treatment failure).

The study was designed to pool some of the advantages of previous prospective and retrospective studies. Objective diagnostic information was consistently accessible from patient records and was not subject to a recall bias (reporting bias). Special data extraction sheets were created retrospectively from existing patient records and study subjects were traced until discharge to ascertain whether their treatment was a functional success or a failure based on study’s assessment criteria. Teeth diagnosed as having failed were compared against teeth that were functionally successful. The purpose was to determine whether the two groups differed in the proportion of teeth exposed to risk factors.

There is a concern about the bias caused by having the same researcher (author) performing the analysis and assessment. However the researcher abstracting the records and performing the analysis and assessment was not the treating dentist. The patient's record was reviewed and analysed in entirety according to the chronological order of the visits until the pathological changes were detected. After determining the type and progress of pathological changes, each radiograph was analysed till the tooth had either been retained or extracted. This systematic evaluation, according to the methodology of the study, ensured consistency of evaluation and eliminated the problem of inter-observer variability. Subsequently, the comparison between the radiographs was made by author and a random sample of radiographs was independently reviewed by a senior consultant under identical standardised conditions. The findings were compared, and the outcome was assessed, and as a final consensus agreement was reached.

Appropriate statistical analysis is an important part of treatment prognosis studies. The major issue to address is the problem of interdependence of variables influencing the outcome. The study recruited any anterior permanent tooth sustaining traumatic injuries leading to avulsion. Although these teeth had been treated under three different treatment protocols (Gregg and Boyd 1998, Flores et al., 2001, Flores et al., 2007) the comparison of success rates using these three protocols did not show any significant difference. Nevertheless any avulsed teeth that were not replanted, cases with root fracture, autotransplantation cases, and cases who had sustained subsequent trauma after replantation were all excluded from the study. Although this may have resulted in loss of some power in evaluating coefficients for the logistic regression models, the sample sizes were sufficient to fit valid models.

Recent clinical studies used different classifications of postoperative outcomes (Pohl et al. 2005) based on analysis of radiographic findings and classified the postoperative healing as functional healing, replacement resorption and infection-related (inflammatory) resorption. Another recent study (Petrovic et al. 2010) classified postoperative outcomes according to the classification used by Pohl et al. 2005. Chappuis and von Arx in 2005 classified periodontal healing according to Fuss (Fuss et al. 2003) as surface resorption (repair-related root resorption), inflammatory resorption (infection-related root resorption) and replacement resorption (ankylosis-related root resorption). Soares (Soares et al. 2008) depending on clinical and radiographic findings classified the postoperative outcomes as complete success, acceptable success, uncertain success, or failure. During this study, the clinical diagnosis was based upon whether the tooth pulp and the root have any pathological changes and/or periapical involvement. However a tooth that was retained, with some pathological changes (root resorption), in the absence of an abscess or sinus tract of pulpal or endodontic origin but ultimately planned for extraction when the patient was more than 17 years old, was classified as a functional success as the tooth was functioning and maintaining keeping the surrounding alveolar bone. This approach agrees with Trope's and McIntyre's definition of success, that maintaining the avulsed and replanted tooth and surrounding bone for a few years can be considered a successful treatment in the growing patient (McIntyre et al., 2007, Trope et al. 2011). This may effectively minimize a positive association between a risk factor and outcome.

Odds ratios (OR) were calculated for all clinical diagnostic variables. Some of the variables showing no association appeared statistically significant such as EADT. This is probably due to the effect of the classification criteria or sample size and identifies the need for further studies to support the results. Given the nature and specificity of this type of trauma and the resulting treatment these variables were pooled together to form two groups based on the clinical consequences. Only variables that had a significant association ($P < 0.05$) with the outcome at an early stage after avulsion were considered in the first prediction model ('initial visit') i.e. dry storage medium, immature roots and younger age. Storage medium itself is not a reason for failure, but is a strong indicator of severe progressive root resorption that may result in early treatment failure. In the same way, variables that had a significant association ($P < 0.05$) at the 'initial treatment visits' (10-45 day after replantation) were involved in second predication model, i.e. Tooth mobility, either after splinting or after starting root canal dressing. In this study, recording of tooth mobility greatly reduced a favourable prognosis.

Signs of healing and maintenance of vitality is possible, especially in teeth with open apices where the pulpal repair seems to be more rapid because of the great chance of revascularisation of the pulp tissue (Kling et al., 1986, Andreasen et al., 2007). A clinical study showed that 77% of teeth with complete root formation demonstrated pulp necrosis compared with 8% of teeth with immature roots (Andreasen and Pedersen 1985). Giving a tooth a chance to maintain vitality and revascularisation, especially for teeth with an immature root is important as this will allow the root to complete its development in terms of both its length and the thickness of its dentinal walls. In contrast, the process of inflammatory resorption can be very rapid and aggressive and may lead to the loss of the tooth as early as three months after replantation, especially in immature rooted teeth (Andreasen et al., 2007). Root resorption is more aggressive in younger aged children for the reason that at this age the dentinal tubules are larger, and the distance from pulp canal to the root surface is small. At the same time, the activity of osteo-odontoclastic cells is amplified if the inflammation occurs as a consequence of the pulp necrosis (Berman et al., 2007). The results of this study have confirmed this using different methodology; it showed that there was significant association between the stage of root formation and the treatment outcomes in terms of survival of replanted avulsed teeth; teeth with completely formed roots had a greater survival rate compared to the teeth with developing roots (n=105, $P \leq 0.001$).

In the overall data analysis, Extra Alveolar Dry Time (EADT) was not a factor associated with the outcomes of the treatment (n= 82, $P = 0.102$). However it is an important observation that the majority of successful cases had a short EADT. Root resorption, its progression and severity in addition to ankylosis were excluded from a prediction model as they were considered as outcomes features.

6.7 Conclusion

The early clinical variables that were most predictive of treatment outcome were patient age, stage of root formation, storage medium, tooth mobility after dressing and tooth mobility after splinting. Given the current findings these models enable a clinician to estimate the long term prognosis of avulsed and replanted teeth and will make it easier to plan for further treatment with a realistic view of outcome at an early stage.

Chapter VII – General Discussion

7.1 What was already known, and what were the gaps in knowledge?

7.1.1 Paediatric facial injuries

Numerous studies have been published internationally with regard to the epidemiology of facial injury in the paediatric population and they report a prevalence of between 1% to 15% (Haug and Foss 2000, Levin et al., 2010, Kidd et al., 2010). This suggests that although facial injury is less common in childhood it is still a significant cause of morbidity and presentation in hospital emergency departments (Zerfowski and Bremerich 1998, Hogg et al., 2000, Shaikh and Worrall 2002, Gassner et al., 2004, Islam et al., 2006, Rahman et al., 2007, Eggensperger et al., 2008, Imahara et al., 2008, Vyas et al., 2008, Al-Malik 2009, Levin et al., 2010, Kidd et al., 2010). The causes of facial injury in childhood would appear to be multifactorial and include falls, interpersonal violence, motor vehicle incidents and other non-intentional causes. More recently the pattern, magnitude time trends, and key socio-demographic determinants of facial injuries in Scottish adults admitted to hospital have been reported (Conway et al., 2010). The authors found a clear and significant association with socio-economic deprivation. Additionally, another recent study has questioned the prevalence, mechanisms of cause, and anatomical location of such facial injuries in children and adolescents (Kidd et al., 2010). The socio-demographic determinants of facial injuries in the paediatric population in Scotland have not previously been studied or reported and the question of whether such injuries are equally distributed across all socio-economic groups has not been answered.

7.1.2 Paediatric dental injuries

Traumatic dental injuries in children and adolescents are a common problem and numerous studies have reported that the prevalence of these injuries has increased over the past few decades (Andreasen and Ravn 1972, Hedegard and Stalhane 1973, Schatz and Joho 1994, Elisa et al., 2000, Andreasen et al., 2007, Andersson et al., 2010). Furthermore, treatment is often complex, and there may be irreversible sequelae, which will require treatment over the patient's entire life (Glendor et al, 2001, Andreasen et al., 2007, Glendor 2008). One of the effects of dental trauma, on anterior teeth especially, is a loss of vitality of the dental pulp (Andreasen and Pedersen 1985, Adeleke et al., 2007). It is generally accepted that the most favourable prognosis for a tooth with an irreversibly necrotic pulp is obtained by providing appropriate endodontic therapy (Ørstavik and Ford 2008). The success and survival rates of root canal treatment are considered to be less than that for implants. Nevertheless it is considered preferable to keep the tooth rather than extract it and place an implant 'superiority of tooth preservation' (Scott et al., 2006). A successful outcome for root canal treatment depends on sufficient disinfection within the canal system combined with an adequate restoration that provides a satisfactory coronal seal (Briggs and Scott 1997, Peak et al., 2001). The evaluation of the outcomes of both pulp therapy and endodontic treatment are important aspects for the development of criteria to further improve diagnostic, treatment, and post treatment recommendations (Lazarski et al., 2001). However, reports on treatment outcomes vary considerably with regard to the incidences of success and failure. The large amount of literature is characterised by a great diversity in the reported outcomes (Robert and Lian 2004). This diversity suggests that direct comparisons among these studies are problematic. However, most of these studies have dealt with non-surgical root canal treatment (NSRCT) consequent to a variety of causes (such as dental decay or for a prosthetic purpose but excluding dental trauma) (Lazarski et al., 2001, Imura et al., 2007). Despite the vast information presented, answers to the main question related to the prognosis of pulpal and endodontic treatment among traumatised teeth have remained obscured by the non-standardised material and methods of many studies. A general review of these mixed studies could be ineffective and potentially ambiguous. At the same time, answers to the questions with regard to the sequelae and the prognosis of pulpal and endodontic treatment among traumatised teeth require a new study that focuses on cases selected according to well defined criteria (Ørstavik and Ford 2008).

Trauma to the anterior teeth and especially the maxillary incisors has a greater social impact compared to functional or psychological development, especially among 12 to 14 year-old children (Fakhruddin et al., 2008).

Avulsion injuries are distressing injuries and can affect the daily life of both patients and their parents compared to families without any history of trauma (Cortes et al., 2002), and could affect the quality of life negatively (Caglayan et al., 2009, Aldrigui et al., 2011). Furthermore, dental avulsion impaired oral health quality of life, especially in young patients (Giannetti et al., 2007). Avulsion injuries are emergencies that require immediate treatment, aiming to reduce any suffering in addition to minimizing the chances that any complication might occur (Andreasen et al., 2007, Andersson et al., 2010). Loss of tooth vitality is frequent sequelae to avulsion injuries. If pulp necrosis is diagnosed late, severe damage such as root resorption or arrested root formation will occur. On the other hand, endodontic treatment can provide a good chance of long term retention for the avulsed teeth. It has been acknowledged for a long time that a replanted tooth following avulsion may function for many years and the healing following replantation has been extensively studied. Under ideal conditions, complete healing of the pulp and the periodontal ligament can occur after replantation (Andreasen et al., 2007). However, such conditions rarely occur in ‘real life’, and as a result the replantation of avulsed teeth is often considered a temporary measure, providing a patient with a natural tooth until its replacement by prosthesis. Despite the vast amount of information reported in the literature, the association between early clinical variables and treatment outcomes remains obscure and it is still not possible to predict the outcomes of the treatment.

7.2 What was the basis for interest in these areas of study?

Interest in, and research on characteristics and trends of paediatric facial and dental injures in Scotland and how socio-economic factors influence an individual’s health came from a concern that these aspects have not previously been explained. This interest was encouraged and stimulated by research in recent years (Conway et al., 2010) which showed clearly that socio-economic deprivation leads to inequalities in the risk of facial injuries among adults.

Similarly interest in, and research on treatment outcomes of dental trauma came from recognition that evaluation of the outcomes of both pulp therapy and endodontic treatment was a critical aspect in the development of criteria to further improve diagnostic, treatment, and post treatment recommendations (Lazarski et al., 2001). This interest was encouraged and stimulated by most of the previous studies that have dealt with NSRCT consequent to a variety of causes (i.e. dental decay or for a prosthetic purpose but excluding dental trauma) (Lazarski et al., 2001, Imura et al., 2007).

As a parent of young children myself I fully appreciate that dental avulsion is one of the most distressing dental injuries both for children and their parents. These injuries adversely affect quality of life, especially as the majority of avulsion injuries carry a poor prognosis even with treatment. For these personal reasons I chose avulsions as one of the subjects for my research to add to their significant academic interest to me as a clinician.

This thesis has attempted to present new evidence via a range of epidemiological approaches which investigate the risk of developing facial and dental injuries among the paediatric population and via analytical approaches which aim to evaluate and predict treatment outcomes.

7.3 Why was it important, and why did this area merit further study?

Given the gaps in scientific knowledge, and the limited utilisation of social epidemiology approaches in existing research, especially on facial and dental injuries among the paediatric population in Scotland, the importance of taking forward this research became apparent.

Research into the nature of the problems and effects of health inequalities together with evaluation of interventions to reduce them are important in providing an evidence base for policy making and clinical care. Furthermore, epidemiological studies done in a large patient population and over a long follow-up period can provide useful tools for clinical decision-making and assessment of treatment prognosis.

7.4 How original was the approach?

There is significant originality in the approaches undertaken within the thesis. Although social inequality is not an entirely new direction for public health research this thesis has taken the problem of Scottish paediatric facial and dental injures and socio-economic inequalities and explored it in more detail for the first time.

In Chapters VI and V, it could be seen that an approach that brings together both descriptive and analytical studies to investigate the risk of facial and dental injuries is not in itself new (Conway et al., 2010, Kidd et al., 2010). However, descriptive epidemiology of facial and dental injury for the paediatric population in Scotland is itself an underexplored field and no such investigation of trends in these injuries had been undertaken until now.

While there had been much development in dental traumatology with regard to examining dental trauma and the treatment outcomes of trauma, there is limited research in this area with regard to prognostic prediction. This body of work (Chapter VII), as far as the author is aware, is the first concerted attempt to consider the early clinical variables (at initial presentation and within the first treatment visits) in relation to dental trauma and prediction of treatment outcomes.

7.5 Has the thesis achieved what it set out to do?

This thesis set out initially to establish the epidemiology of facial injuries in the paediatric population requiring in-patient hospital admission in Scotland. It was then decided to analyse the pattern, time trends, and key socio-demographic determinants, as the interest developed more from an epidemiology perspective. To these ends an initial descriptive epidemiology study (Chapter III) was undertaken which was expanded in scope to include the whole of Scotland. It comprehensively investigated the incidence rates and trends of facial injuries over time for Scotland, by age-group, gender, aetiology and geographical region. Following this initial piece of work, the subsequent part of this study (Chapter III) became centred on investigating whether the extent and the incidence burden of facial injuries was related to socio-economic circumstances, and to assess inequalities in the distribution of facial injuries.

Chapter IV explored the epidemiology of dental trauma in the paediatric population (Primary one) in Scotland. It comprehensively investigated the incidence rates and trends of dental trauma over time for Scotland, by gender, deprivation score (DEPCAT) and geographical region (Health Board). Similarly to the facial injury study (Chapter III with methodological research), the subsequent part of this study became centred on investigating the extent of the incidence burden of dental injuries related to socio-economic circumstances, and in assessing the inequalities in the distribution of these dental injuries. However, the original plan was to include Primary seven school children (P7) in this study and to investigate and contrast with Primary one. Unfortunately this was not feasible as Primary seven (P7) data was not accessible to us at the time of this study.

Chapter V retrospectively investigated and assessed the sequelae of non-surgical root canal treatment in traumatised anterior permanent teeth and determined the magnitude of the factors associated with the outcomes involving patients referred to Glasgow Dental Hospital and School (secondary referral centre).

Chapter VI extensively investigated the replanted avulsed teeth, identified the factors associated with the development of clinical consequences of avulsed teeth and assessed the treatment outcomes. An attempt was made to utilise these results to apply contemporary statistical methods to determine the magnitude of these variables on the outcomes.

Therefore, the thesis achieved in many ways what it set out to do.

7.6 What did this thesis contribute to knowledge?

In addition to what has already been discussed, it is worthwhile reflecting on the contribution and potential contribution of these studies to the research base.

This thesis has made a contribution in several areas. The descriptive elements have described the ‘recent’ trends in facial and dental injuries among the paediatric population across Scotland related to age, gender, aetiology, socio-economic circumstances and geographic region.

The socio-demographic analysis has improved our understanding of the extent that socio-economic trends play in paediatric dental and facial injuries in Scotland. The findings in chapters III and IV will now become a baseline reference of the recent burden of dental and facial injury for further research into the importance of socio-demographic determinants in dental and facial injuries.

The retrospective descriptive analysis of dental trauma and especially dental avulsion (chapter V and VI), have enabled us to identify and determine the clinical variables that were most predictive of treatment outcomes and have permitted us to develop models that will enable prediction of outcomes for future replanted avulsed teeth. A clinician will be able to estimate the long term prognosis of avulsed and replanted teeth and this will make it easier to plan further treatment with a realistic view of outcome at an early stage. This is the first study to have looked at the effects of clinical variables on the outcome of avulsed and replanted teeth and to have developed a prediction model to predict prognosis.

7.7 Main findings and implications

7.7.1 Paediatric facial and dental injuries in Scotland

The study in Chapter III of this thesis is the first and the largest undertaken to report the pattern, time trends, and key socio-demographic determinants of paediatric facial injury in Scotland. The results of this part of the research revealed that paediatric facial injuries were not a common cause of childhood morbidity and accounted for only 0.05% of the total population under 18 years old in Scotland. However they still represent a considerable health burden and most injuries are preventable. In Scotland there was a considerable variation in the relative risk of facial injury by Health Board area. Facial injury in the adult population is most commonly sustained as a result of interpersonal violence, motor vehicle incidents, sports, falls or other non-intentional injuries (Hutchison et al., 1998, Shaikh and Worrall 2002, Roccia et al., 2010). In the adult population in Scotland the most common cause is interpersonal violence (Hutchison et al., 1998, Oakey et al., 2008). In this study the aetiology of facial injuries in the paediatric population varied considerably according to region with the vast majority of facial injuries resulting from non-intentional injury. There was a clear and significant association between the level of socio-economic deprivation and risk of facial injury. SIMD 1 (the most deprived) had a relative risk of 1.89 compared with 1.0 in SIMD 5 (the least deprived) ($p<0.001$). This risk is emphasized when alcohol is involved. This endorses the point that the compositional characteristics of the population in residential areas affect the risk of injury to varying degrees (Reimers and Laflamme, 2005).

Chapter IV of this thesis is the former and the largest approach undertaken to report the pattern, time trends, and key socio-demographic determinants of paediatric dental injury in Scotland. This part of the research revealed that paediatric dental injuries were not a common cause of childhood morbidity and accounted for only 0.6% of the total paediatric population in Scotland (P1 school children) during the study period 1993-2007. Nevertheless they still represent a considerable health burden. At the same time, this study shows, as demonstrated in previous studies conducted by other authors (Hargreaves et al., 1999, Kramer et al., 2003, Oliveira et al., 2007, Avsar and Topaloglu 2009, Jorge et al., 2009, de Amorim et al., 2011) that no significant difference was found in the incidence rate of trauma between genders. Based on this study and its population, no significant association between the risk of dental injuries and level of deprivation was revealed. This is the first time that such a social investigation into dental injuries has been examined so comprehensively at a Scottish level.

In the same way as the facial injuries incidence (Chapter III) there was a considerable variation in the risk of dental injury by NHS Health Boards (areas) and the analysis showed that the rates for sustaining dental injuries in each NHS Health Board (area) varied significantly. There was a significant association between the risk of dental injuries and living in certain areas. In the absence of knowledge about the place (location) and cause of injury it would be hard to ascertain why this variation exists.

These findings have several implications for public health significance. They provide policy makers with an additional evidence-based resource that, in combination with other tools, has the potential to inform measures which contribute to improved child health. This study emphasises that health promotion, prevention and parenting programmes should be implemented using culturally and educationally appropriate tools aiming to reduce all injuries with a special emphasis on non-intentional injuries and interpersonal violence and to increasing knowledge and changing behaviour especially toward prevention, for young people living in areas of multiple social deprivation. However this may not go far enough and political measures to improve the environment, community safety, and community cohesion should also be considered.

7.7.2 Dental trauma and treatment outcomes

The retrospective analysis of dental trauma at a local level in Chapter V revealed that age is a well-documented risk factor, and although dental trauma has been observed in all age groups, this study demonstrated that more traumatic incidents occur in the 9–11 year age group. These results are in agreement with other literature. In this study, as in those conducted by other authors, there was a male predominance (66.6% males and 33.3% female). The environment and the type of activities are the most important factors in dental trauma occurrence (Glendor 2008, Glendor 2009). In this study falls were the most frequent cause of trauma, followed by sports accidents. The most frequent type of trauma sustained was enamel dentine fracture with pulp exposure. Mild trauma, such as concussion and subluxation is not frequently reported because they are less serious and heal faster, and often result in parents not seeking treatment. In this study the type of trauma was a strong predictor of treatment outcomes and was significantly associated with the treatment outcomes ($P < 0.001$). These findings support the evidence-based treatment guidelines for dental trauma (Andreasen et al., 2009).

The results revealed that males are at higher risk of having a subsequent trauma on the same tooth at different times which emphasises the discussion about male: female prevalence. Subsequent trauma was responsible for some of the complications (failure) noted in this study. This highlights the fact that further studies are needed to evaluate what factors are associated with dental trauma recurrence. Delays in treatment can also have adverse effects on long-term outcomes (Hamilton et al., 1997, Batstone et al., 2004). However, this study found no significant association between the time that elapsed until receiving initial treatment and outcome. Nevertheless the most successful treatments were recorded among those cases which received early treatment. Lack of information about dental trauma and the consequences of dental trauma might be responsible for delays in seeking dental care after a traumatic injury, and this should be considered in any community based initiative. This part of the research highlights the importance of raising the public awareness of dental trauma and its consequences and the importance of the development and implementation of educational programmes to teach parents and teachers how to avoid falls and how to provide first aid in dental trauma incidents.

According to this study, many factors could have an influence on the treatment outcomes of traumatised teeth; type of trauma; stage of root development; quality of temporary filling (in terms of stability and leakage); tooth mobility after dressing; and extra alveolar dry time (for avulsed teeth). However, further studies are recommended with larger numbers in each trauma category in order to clarify the relevance of these clinical variables. Though, the number of cases recruited fell short of an estimated power calculation and therefore the generalised conclusion from this part of the research cannot be drawn or extrapolate from such small numbers, which indicates that a larger sample size is required.

7.7.3 Dental avulsion and treatment outcomes

The descriptive retrospective analysis in Chapter VI was designed to pool some of the advantages of previous prospective and retrospective studies. The main observations emanating from this study were the magnitude of risk that dry storage medium, immature roots and a younger age exert on the outcome (treatment failure) at 'initial treatment stage' after dental avulsion and replantation (first visit after trauma), and the magnitude of risk that the recording of tooth mobility, either after splinting or after commencement of root canal dressing exerts on the outcome at 'initial treatment visits' after avulsion (10 to 45 days after trauma). The analysis in chapter VI showed no statistically significant association with regard to EADT. This is probably due to the effect of the simple classification criteria used and of the study samples size. This identifies the need for further studies to support the results. This is one of the first studies to have looked at the effects of clinical variables on the outcome of avulsed and replanted teeth and to have developed prediction models to predict prognosis for avulsed and replanted teeth. Given the current findings these models will enable a clinician to estimate the long term prognosis of avulsed and replanted teeth and will make it easier for the clinician to plan for further treatment with a realistic view of outcome at an early stage.

7.8 Study limitations

It is important to review the research limitations. They relate to the limitations of epidemiology in general, and the specific study designs employed in the research. In drawing attention to the limitations it is visualized that the strengths of the research approaches taken will also be highlighted. Further, reflections on such limitations encourage further ideas and research approaches which could be used to improve our knowledge of the subject when similar research is repeated. Thus, the major limitations of the research will be discussed in the chronological order that the studies were presented namely: facial injuries, dental trauma, and dental avulsion.

The main strength of the facial injuries study is that it was population based and included all the denominators needed for direct calculation of injury rates in children for a given Health Board (area) or region. Other strengths related to the length of the recruitment period and that the analysis was of a longitudinal documentation of paediatric facial injuries over the whole of Scotland. Despite these advantages there were inherent deficiencies due to the retrospective nature of the study. The study was designed to minimise the possibility of bias as all subjects were included with no exclusion categories. In addition the study covered all of Scotland including urban and rural areas, thereby providing a sample that reflected the general population as closely as possible. The main limitation of this study was that it did not include those subjects with facial injuries who were treated and discharged in the emergency departments or out-patient clinics, quite apart from those subjects who did not seek help for the treatment of their injuries because presumably those injuries were too minor. This study therefore underestimates the true extent of paediatric facial injury in Scotland as SMR01 entries are only generated for in-patient episodes. In future therefore there is a need to develop a standardised method of collating and retrieving data for out-patient facial injury episodes.

In the same way, the dental injuries study covered all areas of Scotland including urban and rural areas, thereby providing a sample that reflects the general population as closely as possible. It was based on the data from two valued and respected programmes in Scotland (SHBDEP and NDIP) which aim to assess every child's dental wellbeing. These two programmes provide an essential source of information for keeping track of any changes in the dental health of children in Scotland. Despite these advantages there were also inherent deficiencies due to the nature of and the method of oral inspection during these programmes; the inspection involves only simple visual assessment of the mouth of each child using a light, mirror and probe. This mean that all reported trauma cases were visible in the mouth during dental inspection and this will under-report the true extent of paediatric dental injury as it does not cover all dental traumatic injuries. At the same time, the main limitation of this study was that it did not include those subjects with dental injuries who were registered at private schools (not target population of SHBDEP and NDIP), quite apart from those subjects who did not get recruited (not sampled) in the two programmes. Therefore, there is an underestimation of the true extent of paediatric dental injury in Scotland. In addition, because of the nature and the main purpose of these two programmes (to determine levels of tooth decay) there is a lack of data about some important variables such as the place (location) of injury and the cause of injury which make it difficult to interpret and determine some variations. More in-depth data collection is required in order to target interventions for prevention and there is a need to upgrade and develop a standardised method of collating and retrieving data for National dental injury cases.

The dental avulsion study recruited any anterior permanent tooth sustaining traumatic injuries leading to avulsion that had more than one year of follow up or until failure. Only one tooth/patient was recruited and excluded teeth were: complicated trauma cases such as avulsion with crown-root#; root fractured teeth; teeth that were not replanted; autotransplanted teeth; and teeth that had sustained subsequent trauma. This may have resulted in loss of some power in evaluating coefficients for the logistic regression models.

The main limitation of this study was that the collected data included teeth examined and treated under three different treatment protocols (Gregg and Boyd 1998, Flores et al., 2001, Flores et al., 2007). Nevertheless a comparison of success rates using these three protocols did not show any significant difference. The analysis of this part (Chapter VI) of the thesis revealed that some variables showed no association but nearly achieved statistical significance. This is probably due to the effect of the outcomes assessment criteria used or might be that the sample size was too small which identifies the need for further larger studies to support the results. However, the sample sizes were deemed sufficient to fit valid models and allow the conclusions to be drawn. In addition, the definition of treatment outcomes "functional success" and "failure" were time-dependent and not clinical standard criteria, but based on the supposition that maintaining the avulsed and replanted tooth and its surrounding bone for even a few years in the growing patient can be considered a success (McIntyer et al., 2007, Trope et al. 2011). This may effectively minimize a positive association between a risk factor and outcome. However, the time interval between initial treatment and functional success/failure was ignored for the reason that we were not interested in the time to failure, only the continued function of the re-implanted tooth. Also, in this study there were differing numbers of missing data for each possible predictor (study variables).

7.9 Further research

There is a range of further research projects that could inform and complement the current work. The following are some examples that would cover some of the current gaps in this research.

- The facial injuries that were investigated were only the more serious cases (in-patient cases), but these are probably only a small proportion of the total injuries and it would be of significant value to add information about the less serious injuries (treated and discharged in the emergency departments or outpatient clinics), as these also might have a large impact on human suffering (morbidity).

- To continue to support and conduct research into the circumstances during which facial injuries occur and to develop and test appropriate preventive countermeasures.

- The extent to which gender factors explain the burden of facial injuries in relation to behavioural factors needs to be investigated.

- The explanation of socio-economic inequalities for facial injuries remains unanswered. This includes determining which component of the socio-economic statistics and circumstances are the most important (i.e. individual or area factors).

- The economic burden of facial injuries needs to be studied and expanded to include all patients (in-patient and out-patient). Further extension of the current Scottish study to include all of the UK would be both feasible and useful. However, getting the research to cross national barriers could pose a significant difficulty because of funding issues.

- The dental trauma study should be expanded to include P7 children and private schools. This would lead to a more accurate understanding of the extent of paediatric dental injury. This research would target more in-depth data about some important variables such as the place (location) and cause of injury which would help the interpretation and explanation of the data.

- Further study to evaluate the factors associated with dental trauma recurrence, especially among males is indicated. Consideration should be given to recruiting a larger sample (multi-centre) and then to study each trauma category separately. This would help to evaluate the factors affecting treatment outcomes.

- In the dental avulsion study there was a concern about those variables that showed no association but which nearly achieved statistical significance and about the effects of sample size and assessment criteria on the results. Further multi-centre studies are needed to achieve significantly increased numbers which would also allow further in-depth assessment.

Chapter VIII – General Conclusion and Recommendations

8.1 Thesis conclusion

This thesis addresses two topics: Facial injuries and Dental trauma, both among the paediatric population. Chapters III and IV of this thesis present the epidemiology of facial and dental injuries among the Scottish paediatric population. Chapter V presents the occurrence of paediatric dental trauma and its general treatment outcomes, focusing specifically on dental avulsion in Chapter VI. The thesis has four studies: the first two used valued and respected datasets of programmes in Scotland (Information Services Division in Scotland (ISD), Scottish Health Boards Dental Epidemiological Programme (SHBDEP) and National Dental Inspection Programme (NDIP) to examine facial and dental injuries sustained by children and adolescents. The other two studies used the dental trauma dataset of a secondary referral centre (Glasgow Dental Hospital and School (GDHS).

The general conclusions of these studies will be presented in terms of the aims as outlined in Chapter I (p 4-5).

- ***Epidemiology of facial injuries among the Scottish paediatric population:***

The incidences of facial injuries requiring in-patient care in the paediatric population in Scotland were not a common cause of childhood morbidity and accounted for only 0.5% of the total population under 18 years old. At the same time these incidences have decreased over time from 5.5 per 1000 population in 2001 to 4.0 per 1000 population in 2009. Nevertheless facial injury requiring in-patient care in the Scottish paediatric population continues to represent a considerable social and healthcare burden, particularly when the majority of injuries were due to preventable causes. There was a very strong association between social deprivation and facial injury with a significant increase in risk in more socially deprived communities. This risk is accentuated when alcohol is involved. However, the exact mechanism or pathway through which social deprivation factors impact on the incidence of facial injuries is unknown. It was not possible to assess which of the range of potential explanations is the most important.

- ***Epidemiology of dental injuries among the Scottish paediatric population:***

The evidence indicates that the prevalence of dental injuries in the paediatric population in Scotland (Primary one) is very low (0.6%), and that the incidence of these injuries has decreased over time from 9.5 per 1000 population in 1993 to 3.0 per 1000 population in 2007. However, dental injury in the Scottish paediatric population continues to represent a considerable social and healthcare burden particularly when the majority of dental injuries are due to preventable causes. In addition, it was confirmed that there was no association between genders, social deprivation and dental injury at this age (Primary one).

- ***Paediatric dental trauma and treatment outcomes at a secondary referral centre:***

Dental trauma occurs more frequently in the age group 9 -11. The most common type of dental trauma was enamel-dentine fracture with pulp exposure. Falls and sporting accidents were the most common causes of dental trauma, while houses, schools and streets were the most frequent locations of dental trauma. Males were more vulnerable to dental trauma and especially to subsequent trauma. Based on this study the success rate of pulpal/endodontic treatment among traumatised anterior permanent teeth was just above 50% and the factors that have an influence on the treatment outcomes are: type of trauma; stage of root development; quality of temporary filling (in terms of stability and leakage); tooth mobility after dressing; and extra alveolar dry time for avulsed teeth.

- ***Dental avulsion and treatment outcomes at a secondary referral centre:***

The early clinical variables that were most predictive of treatment outcome for replanted avulsed teeth were: patient age; stage of root formation; storage medium; tooth mobility after dressing; and tooth mobility after splinting. The study resulted in the construction of two models to estimate the long term prognosis of avulsed and replanted teeth. These will enable a clinician to plan further treatment with a realistic view of outcome at an early stage.

The studies involved in this thesis have enabled the aims and objectives to be achieved and fulfilled.

8.2 General recommendations

- The findings should be disseminated to National Health Boards and Trusts in Scotland for consideration when developing future Health Improvement Programmes and Trust Implementation Plans so that appropriately targeted preventive programmes can be formulated.

- The findings should be communicated to NHS departments in Scotland who have a responsibility and a role in improving the recording of oral and general health data. They need to collect more in-depth data and develop a standardised method of collating and retrieving data, especially for dental trauma cases in addition to regularly upgrading and updating the data system and including children at private schools. Similarly there is a need to develop a standardised method of collating and retrieving data for out-patient facial injury episodes.

- The social inequalities identified in the facial injuries data should be shared with the agencies that have an important role in improving oral and general health.

- Health Boards should seek significant investment by government in public health programs aimed at increasing knowledge and changing behaviour with a view to reducing the inequalities in the prevalence of facial injuries.

Presentations

1. Oral Poster presentation at the European Association of Paediatric Dentistry - Leeds 2010

University of Glasgow

Treatment outcomes in traumatised permanent anterior teeth requiring pulp treatment

O.H.Rhouma, J.F. McCord, R.R.Welbury
University of Glasgow Dental School. o.rhouma.1@research.gla.ac.uk
o.rhouma.1@research.gla.ac.uk

Introduction

Traumatic dental injuries in children and adolescents are a common problem and the prevalence of these injuries has increased over the past few decades. The dental pulp might be injured or become infected through trauma and pulp therapy or endodontic treatment are the clinical treatment options in order to maintain the tooth in function in the oral cavity (Friedman 2002, Robert 2004, Ørstavik 2008).

Aim

To identify clinical factors influencing treatment outcomes.

Methods

A descriptive retrospective study. The trauma database was used to identify all patients treated with pulpal and root canal treatment (RCT) as a result of dental trauma (DT) in the period 1994 -2007. A data extraction sheet was completed for each tooth and the data transcribed and processed by SPSS-15 statistical package. The association between treatment outcomes and clinical variables was studied by Fisher's exact test.

Results

89 permanent teeth (63 patients) with pulpal involvement were randomly identified.16 teeth were excluded from analysis (Failed to complete treatment). Male:Female ratio was 2:1 with an average age at time of trauma of 10.31 yrs (SD 2.16 yrs). Dental trauma was most frequent in age group 9-11yrs (53.9%).Upper central incisors most commonly involved (43.8%). Home and the immediate home environs were the commonest location of trauma (18%). Falls (34.8%) and injuries during sport/play (34.8%) were the commonest causes. Enamel-dentine fracture with pulp exposure (34.8%) and avulsion (28%) were the commonest injuries. 59 teeth (66.3%) received a first treatment intervention less than 24 hrs following the injury. Treatment type depended on the severity of trauma. RCT was the most frequent treatment provided especially for avulsion (100%). Criteria used to determine treatment outcomes are shown in **Table-1**. Outcomes were **S**uccess (53.4%); **S**hort-term success but long-term failure (35.6%); and **F**ailure (11%) (**Fig-1**). Significantly fewer failures occurred with: developing roots compared to completed roots (*p=0.05*) (**Table-2-1**); good quality temporary filling material (**Table-2-2**) and non mobility after commencement of treatment (p<0.000) (**Table-2-3**); extra alveolar dry time (EADT) <1hr *(p =0.02)* (**Table-2-4**). No significance was reached with regard to: extra alveolar time (EAT) (*p=0.191*) (**Table-2-5)**; type of storage medium (*p=0.43*) (**Table-2-6**); condition of root canal (P=0.095) (**Table-2-7**).

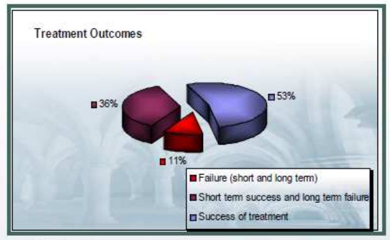


Fig-1: Treatment outcomes.

Success	• Tooth is still in the mouth. • Tooth exhibits normal function. • No evidence of subjective discomfort • Absence of clinical signs and symptoms. • Absence of painful response to percussion or palpation. • Absence of abscess and sinus tract of pulpal or endodontic origin. • Absence of tooth mobility. • Presence of normal periradicular and periodontal ligament structure.
Failure	• Tooth extracted or due for extraction (because of failure of the treatment). • Developing a periradicular lesion which was not present initially or its size has increased after operative treatment. • Presence of periradicular pain, swelling or a sinus tract related to the tooth • Presence of periradicular radiolucency that developed after completion of treatment. • Presence of progressive root resorption.
Short-term success but long term failure	• Tooth or root is retained as a natural space mainatainer until the patient is old enough to receive further treatment (implant or fixed prosthesis).

Table-1: Outcomes categories.

	Treatment outcomes						
	Failure		Short term success		Success		P-Value
	%	(n)	%	(n)	%	(n)	
1- Stage of root formation (n=73)							*0.05*
2/4(Parallel)	0%	(0)	0%	(0)	100%	(1)	
3/4 (Convergent)	0%	(0)	50%	(2)	50%	(2)	
4/4 (open apex).	0%	(0)	45.2%	(14)	54.8%	(17)	
4/4 (completely formed).	21.6%	(8)	27%	(10)	51.4%	(19)	
2- Quality of Temporary Filling (n-73)							*> 0.000*
Good seal (in place)	5.6%	(2)	27.8%	(10)	66.7%	(24)	
Not good (loos>1time)	21.1%	(4)	26.4%	(5)	52.6%	(10)	
Not cited	11.1%	(2)	61.1%	(11)	27.8%	(5)	
3- Mobility after treatment (n=73)							*> 0.000*
No	2.3%	(1)	18.6%	(8)	79.1%	(34)	
Yes	23.3%	(7)	60%	(18)	16.7%	(5)	
4- Extra Alveolar Dry Time (n=22)							*0.02*
>1hr	0%	(0)	50%	(2)	50%	(2)	
1hr- 2hrs	100%	(2)	0%	(0)	0%	(0)	
< 2hrs	33.3%	(2)	33.3%	(2)	33.3%	(2)	
Not specified	11.1%	(1)	88.9%	(8)	0%	(0)	
5- Extra Alveolar Time (n=22)							*0.191*
>1hr	0%	(0)	100%	(2)	0%	(0)	
1hr- 2hrs	50%	(2)	0%	(0)	50%	(2)	
< 2hrs	18.8%	(3)	68.8%	(11)	12.5%	(2)	
6- Storage Medium (n=22)							*0.434*
Milk	33.3%	(3)	44.4%	(4)	22.2%	(2)	
Dry paper	50%	(2)	50%	(2)	0%	(0)	
Cotton wool	0%	(0)	100%	(2)	0%	(0)	
Not specified	0%	(0)	71.4%	(5)	28.6%	(2)	
7- Root canal after dressing (n=56)							*0.095*
Dry and clean	6.7%	(2)	36.7%	(11)	56.7%	(17)	
Pus (or any sing of infection)	33.3%	(1)	66.7%	(2)	0%	(0)	
Not cited	17.4%	(4)	52.2%	(12)	30.4	(7)	

Table-2(1-7): Significance of variables

Conclusions

89% of teeth requiring pulp treatment were retained during adolescence facilitating optimal bone growth. Stage of root development, quality of temporary filling, extra alveolar dry time and tooth mobility after commencement of treatment would appear to be significant factors in predicting the final treatment outcomes.

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EAPD 2010
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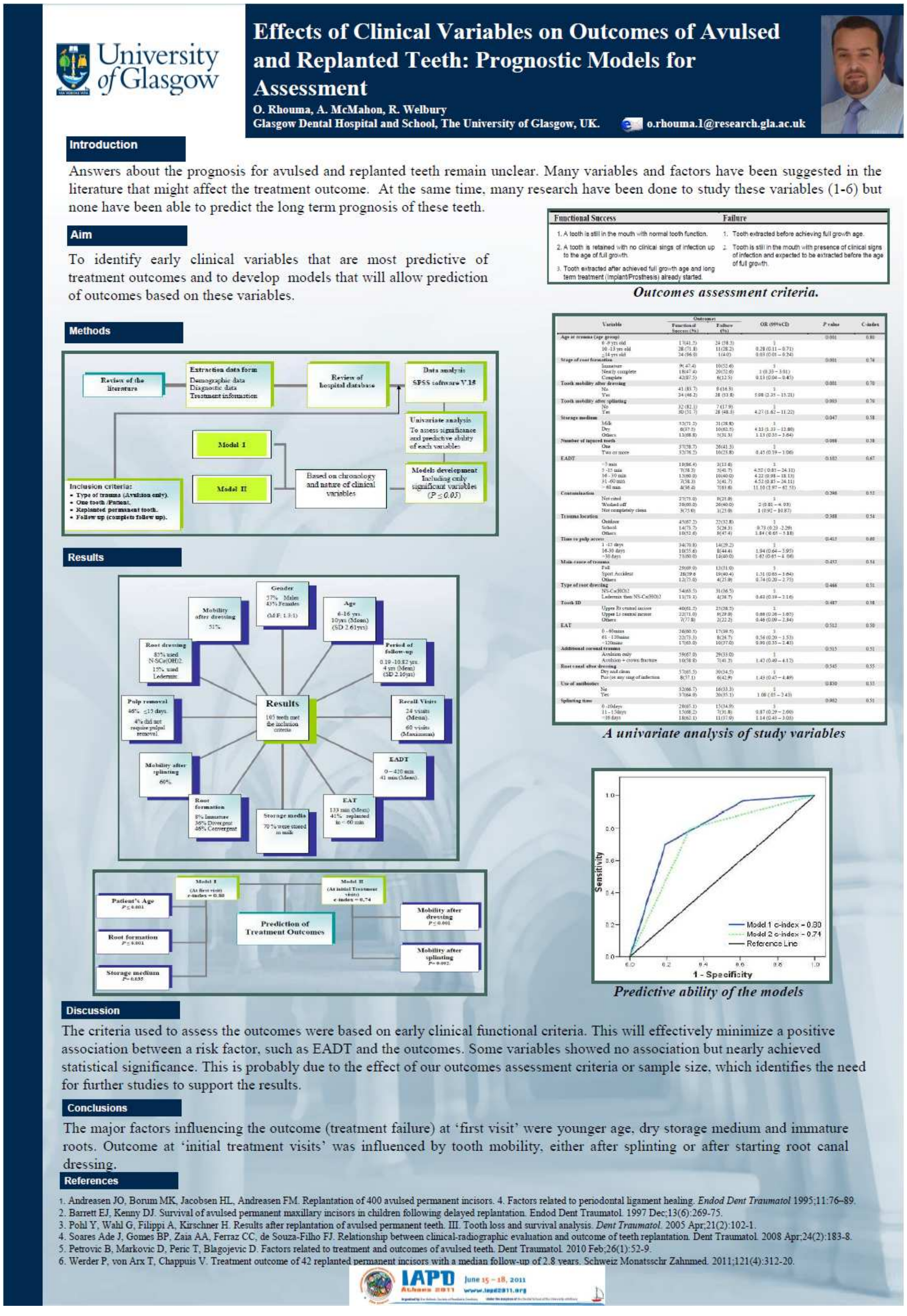
2. Oral Poster Presentation at the International Association of Paediatric Dentistry - Athens 2011



3. Oral Poster Presentation at the British Society of Paediatric Dentistry - Glasgow 2011

University of Glasgow

Dental Trauma in 5 Year Olds in Scotland (1993-2007): A Sociodemographic Analysis

O. Rhouma, A. McMahon, R. Welbury
Glasgow Dental Hospital and School, The University of Glasgow, UK. o.rhouma.1@research.gla.ac.uk

Introduction

Dental trauma is a common occurrence in childhood and can be caused by falls or any other accidents, but to date the major sociodemographic determinants in Scotland have not been reported.

Aim

To describe the pattern, time trends of dental trauma and to assess the key sociodemographic determinants of dental trauma among primary one (5 yr olds) children in Scotland 1993-2007.

Methods

Records of the National Dental Inspection Programme (NDIP) between 1993-2007 were retrieved from the Scottish Dental Epidemiology Coordinating Committee (SDECC). NDIP data involve recording the status of each tooth surface in accordance with international epidemiological conventions (1). Annual incidences of dental trauma were calculated by gender, health board and Carstair's deprivation category (DEPCAT) (2). Data were analysed using SPSS standard version 15.

Results

Between 1993 and 2007 68,398 primary one children were examined and only 405 (0.6%) had suffered dental trauma with an overall incidence of 5.9 per 1000 population.

There was a significant decrease in incidence over time (1999 three times greater than 2007) (Figure 1).

Males were affected more than females with a relative risk (RR) for males 1.12 times greater than females (Figure 2).

Incidence varied significantly between Heath Boards ($p<0.001$); the highest rate being reported in Dumfries (14.2 per 1000 population, RR= 2.54), which was 11 times greater than Ayrshire (1.3 per 1000 population; RR= 0.21) (Figure 3).

There was no significant association between risk of dental trauma and deprivation (P= 0.957). In DEPCAT 1 (most affluent) the incidence rate was 6.4 per 1000 population (RR =1.08), while in DEPCAT 7 (most deprived) the incidence rate was 5.7 per 1000 population (RR =0.95) (Figure 4).

Conclusion

The incidence and RR of dental trauma was: higher for males; those living in Dumfries; significantly decreased since 1993. Deprivation level has no effect on incidence and risk of dental trauma. More in-depth data is required to target interventions for prevention.

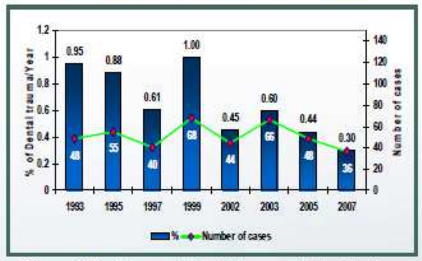


Figure 1. Incidence of dental trauma in Scotland 1993-2007.

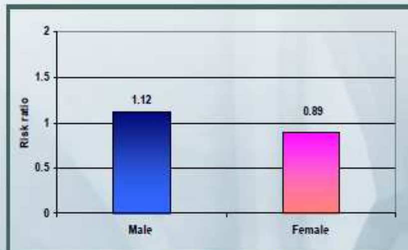


Figure 2. Relative risk of sustaining dental trauma according to gender 1993-2007.

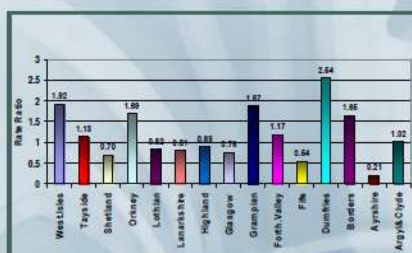


Figure 3. Relative risk of sustaining dental trauma according to Heath Board 1993-2007.

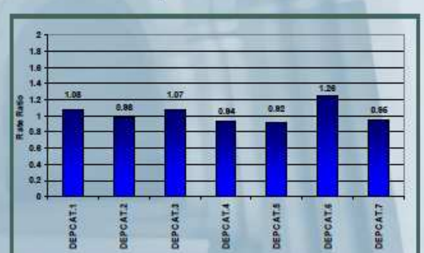


Figure 4. Relative risk of sustaining dental trauma according to DEPCAT 1993-2007.

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The British Society of Paediatric Dentistry

4. Oral Poster Presentation at the International Conference of Oral and Maxillofacial Surgery - Santiago 2011

University of Glasgow

Paediatric Facial Injuries in Scotland 2001-2009: Epidemiological and Sociodemographic Aspects

O. Rhouma[1], A. McMahon[1], D. Conway[1], M. Armstrong[2], K. Welbury[1], C. Goodall[1]
1.Glasgow Dental Hospital and School, The University of Glasgow, Glasgow, Scotland, UK.
2.Information Services Division (ISD), NHS National Services Scotland, Edinburgh, UK.
o.rhouma.1@research.gla.ac.uk

Background

Paediatric facial injuries is not a common occurrence in childhood but it can lead to significant morbidity. However, sociodemographic determinants in Scotland have not previously been reported.

Aim

To analyse and describe the pattern, time trends and key sociodemographic determinants in children and adolescents who have suffered facial trauma.

Methods

Scottish Morbidity records (SMR01) for the period 2001-2009 were retrieved from the Information Services Division in Scotland (ISD)[1]. Annual incidences were calculated by age, gender, health board, SIMD[2] (Scottish Index of Multiple Deprivation) and mechanism of injury. A Poisson regression analysis model was used to incorporate the variables. Statistical analysis was conducted using the SAS statistical software package version 9.1.

Results

Between 2001 and 2009, 45388 (0.05%) of 9,568,185 persons aged 0-17 years had suffered facial injury (4.7 per 1000 population). 60% of injuries were due to non-intentional accidents, with an additional 15% due to traffic accidents, 9% due to assault. 4.5% were alcohol related (Figure 1).

The relative risk (RR) for males was 1.98 times greater than females ($p < 0.001$). The incidence decreased over time from 5.5/1000 in 2001 to 4.0/1000 in 2009 (Figure 2).

RR varied significantly between Heath Boards (areas) from 0.68 (Dumfries) -1.76 (Grampian) ($p < 0.001$) (Figure 3).

There was a significant association between facial injury and deprivation ($p < 0.001$); SIMD 1 (most deprived) has the highest incidence rate of 6.3/1000 population (RR =1.89), while in SIMD 5 (least deprived) the incidence rate was 3.7/1000 population (RR =1.0) (Figure 4).

Conclusions

Among the Scottish paediatric population the incidence and relative risk of facial injury is higher in males living in areas of social deprivation. Many injuries are due to accidents and more needs to be done to direct education and resources towards prevention.

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2. The Scottish Index of Multiple Deprivation (SIMD): http://www.scotland.gov.uk/Topics/Statistics/SIMD/BackgroundMethodology

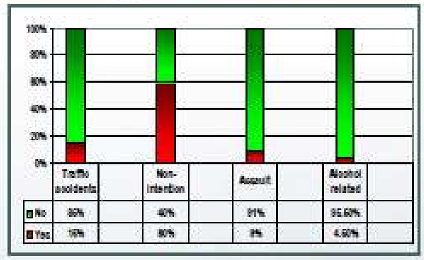

Figure 1. Aetiology of paediatric facial injuries in Scotland (2001-2009).

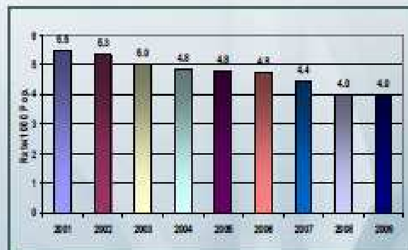

Figure 2. Incidence rate of sustaining facial injuries in Scotland (2001-2009).

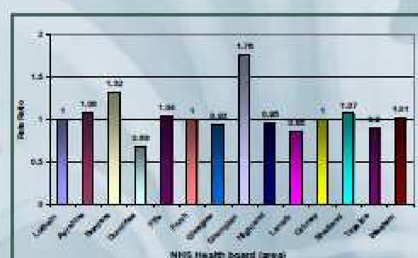

Figure 3. Relative risk of sustaining facial injury according to Heath Board 2001-2009.

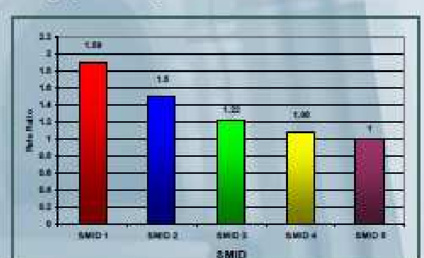

Figure 4. Relative risk of sustaining facial injury according to SIMD 2001-2009.

20th International Conference on Oral and Maxillofacial Surgery
Santiago, Chile, November 1-4, 2011

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Appendices

Appendix 1 Dental Trauma Classifications

Andreasen's classification	*(WHO) classification*	*Ellis classification*
Crown infraction. Incomplete fracture of the enamel	Fracture of enamel of tooth	Simple fracture of the crown, involving little or no dentine
Uncomplicated crown fracture. A fracture confined to the enamel or dentine but not exposing the pulp	Fracture of crown without pulpal involvement	Extensive fracture of the crown, involving considerable dentine, but not the dental pulp
Complicated crown fracture.A fracture involving enamel and dentine, and exposing the pulp.	Fracture of crown with pulpal involvement	Extensive fracture of the crown, involving considerable dentine and exposing dental pulp
Uncomplicated crown-root fracture. A fracture involving enamel,dentine, cementum, not exposing the pulp	Fracture of root of tooth	The traumatized tooth that becomes non-vital,with or without loss of crown structure
Complicated crown-root fracture. A fracture involving enamel, dentine and cementum, and exposing the pulp	Fracture of crown and root of tooth	Total tooth loss
Root fracture.A fracture involving dentine, cementum, and the pulp	Fracture of tooth, unspecified	Fracture of the root, with or without loss of crown structure
Concussion. Injury without abnormal loosening or displacement but with marked reaction to percussion	Luxation of tooth	Displacement of tooth, without fracture of crown or root
Subluxation (loosening). Injury with abnormal loosening but without displacement of the tooth	Intrusion or extrusion of tooth	Fracture of the crown *en masse* and its replacement
Intrusive luxation (central dislocation)	Avulsion of tooth	
Extrusive luxation (peripheral dislocation, partial avulsion)	Other injuries including laceration of oral soft tissues	
Lateral luxation		
Exarticulation (complete luxation)		
Comminution of alveolar socket		
Fractures of facial or lingual alveolar socket wall		
Fractures of alveolar process with and without involvement of the socket		
Fractures of the mandible or maxilla with and without involvement of the tooth socket		
Laceration of gingiva or oral mucosa		
Contusion of gingiva or oral mucosa		
Abrasion of gingiva or oral mucosa		

Source (Ellis 1970, WHO 1978, Andreasen 1981).

Appendix 2 Facial injury ICD-10 codes (Table 1-5)

Appendix 2-Table 1: Facial injury ICD-10 codes:

S00.0	**Superficial injury of scalp**
S00.1	**Contusion of eyelid and periocular area Black eye *Excludes:* contusion of eyeball and orbital tissues (S05.1)**
S00.2	**Other superficial injuries of eyelid and periocular area *Excludes:* superficial injury of conjunctiva and cornea (S05.0)**
S00.3	**Superficial injury of nose**
S00.4	**Superficial injury of ear**
S00.5	**Superficial injury of lip and oral cavity**
S00.7	**Multiple superficial injuries of head**
S00.8	**Superficial injury of other parts of head**
S00.9	**Superficial injury of head, part unspecified**
S01.0	**Open wound of scalp *Excludes*: avulsion of scalp (S08.0)**
S01.1	**Open wound of eyelid and periocular area Open wound of eyelid and periocular area with or without involvement of lacrimal passages**
S01.2	**Open wound of nose**
S01.3	**Open wound of ear**
S01.4	**Open wound of cheek and temporomandibular area**
S01.5	**Open wound of lip and oral cavity *Excludes:* tooth: dislocation (S03.2) Fracture (S02.5)**
S01.7	**Multiple open wounds of head**
S01.8	**Open wound of other parts of head**
S01.9	**Open wound of head, part unspecified**
S02.2	**Fracture of nasal bones**
S02.3	**Fracture of orbital floor *Excludes:* orbit NOS (S02.8) Orbital roof (S02.1)**
S02.4	**Fracture of malar and maxillary bones: superior maxilla, upper jaw (bone), zygoma**
S02.5	**Fracture of tooth, broken tooth**
S02.6	**Fracture of mandible, lower jaw (bone)**
S02.7	**Multiple fractures involving skull and facial bones**
S02.8	**Fractures of other skull and facial bones, alveolus, Orbit NOS Palate *Excludes:* orbital: floor (S02.3) Roof (S02.1)**
S02.9	**Fracture of skull and facial bones, part unspecified**
S03.0	**Dislocation of jaw, jaw (cartilage)(meniscus), mandible, temporomandibular (joint)**
S03.1	**Dislocation of septal cartilage of nose**
S03.2	**Dislocation of tooth**
S03.3	**Dislocation of other and unspecified parts of head**
S03.4	**Sprain and strain of jaw, temporomandibular (joint)(ligament)**
S03.5	**Sprain and strain of joints and ligaments of other and unspecified parts of head**
S04.0	**Injury of optic nerve and pathways, optic chiasm, 2nd cranial nerve, visual cortex**
S04.1	**Injury of oculomotor nerve, 3rd cranial nerve**
S04.2	**Injury of trochlear nerve, 4th cranial nerve**
S04.3	**Injury of trigeminal nerve, 5th cranial nerve**
S04.4	**Injury of abducent nerve, 6th cranial nerve**
S04.5	**Injury of facial nerve, 7th cranial nerve**
S04.9	**Injury of unspecified cranial nerve**
S05.1	**Contusion of eyeball and orbital tissues, traumatic hyphaema, *Excludes:* black eye (S00.1) Contusion of eyelid and periocular area (S00.1)**
S05.4	**Penetrating wound of orbit with or without foreign body *Excludes:* retained (old) foreign body following penetrating wound of orbit (H05.5)**
S05.8	**Other injuries of eye and orbit, lacrimal duct injury**
S05.9	**Injury of eye and orbit unspecified, injury of eye NOS**
S07.0	**Crushing injury of face**
S08.0	**Avulsion of scalp**
S08.1	**Traumatic amputation of ear**
S08.8	**Traumatic amputation of other parts of head**
S08.9	**Traumatic amputation of unspecified part of head *Excludes:* decapitation (S18)**
S09.0	**Injury of blood vessels of head, not elsewhere classified *Excludes:* injury of: cerebral blood vessels (S06.-) Precerebral blood vessels (S15.-)**
S09.1	**Injury of muscle and tendon of head**
S09.2	**Traumatic rupture of ear drum**
S09.7	**Multiple injuries of head, injuries classifiable to more than one of the categories S00–S09.2**
S09.8	**Other specified injuries of head**
S09.9	**Unspecified injury of head, injury of: face NOS, ear NOS, nose NOS**
S10.7	**Multiple superficial injuries of neck**
S10.8	**Superficial injury of other parts of neck**
S10.9	**Superficial injury of neck, part unspecified**
S15.0	**Injury of carotid artery, carotid artery (common) (external) (internal)**
S15.2	**Injury of external jugular vein**
S15.3	**Injury of internal jugular vein**
S15.7	**Injury of multiple blood vessels at neck level**
S15.8	**Injury of other blood vessels at neck level**
S15.9	**Injury of unspecified blood vessel at neck level**
S17.8	**Crushing injury of other parts of neck**
S17.9	**Crushing injury of neck, part unspecified**
S19.7	**Multiple injuries of neck, injuries classifiable to more than one of the categories S10–S18**
S19.8	**Other specified injuries of neck**
S19.9	**Unspecified injury of neck**

Source: http://apps.who.int/classifications/apps/icd/icd10online/

Appendix 2-Table 2: Selected Alcohol diagnostic ICD-10 codes:

F10.0	Mental and behavioral disorders due to use of alcohol (acute intoxification)
F10.1	Harmful use
R78.0	Finding of alcohol in blood
T51	Toxic effect of alcohol
X45	Non-intentional poisoning by and exposure to alcohol
X65	Intentional self-poisoning by and exposure to alcohol
Y15	Poisoning by and exposure to alcohol undetermined intent
Y90	Evidence of alcohol involuntary determined by blood alcohol level
Y91	Evidence of alcohol involvement determined by level intoxication
E52	Niacin deficiency _pellagra_
G312	Degeneration of nervous system due to alcohol
G621	Alcoholic polyneuropathy
G721	Alcoholic myopathy
I426	Alcoholic cardiomyopathy
K292	Alcoholic gastritis
K70	Alcoholic liver disease
K860	Alcohol-induced chronic pancreatitis
Y573	Alcohol deterrents
Z502	Alcohol rehabilitation
Z714	Alcohol abuse counseling and surveillance
Z721	Alcohol use

source : http://www.alcoholinformation.isdscotland.org/alcohol_misuse/files/AlcoholStatisticsScotland2005.pdf

Appendix 2-Table 3: Assault related injuries ICD-10 codes

X.99	Assault with a sharp object (includes stabbed)
Y.00	Assault with a blunt object
Y.04	Assault by bodily force
Y.06	Neglect and abandonment
Y.07	Other maltreatment syndromes
T.74.1	Physical abuse

Source: http://apps.who.int/classifications/apps/icd/icd10online/

Appendix 2-Table 4: External causes related injuries (Transport accidents) ICD-10 codes

V.01	Transport accidents (generally subdivision .0 can be excluded from codes V.30 onwards below as this refers to the driver of the vehicle)
V.01-V.09	Pedestrian injured in transport accident
V.10-V.19	Pedal cyclist injured in transport accident
V.30-V.39	Occupant of three-wheeled motor vehicle injured in transport accident
V.40-V.49	Car occupant injured in transport accident
V.50-V.59	Occupant of pick-up truck or van injured in transport accident
V.60-V.69	Occupant of heavy transport vehicle injured in transport accident
V.70-V.79	Bus occupant injured in transport accident
V.80-V.89	Other land transport accidents
V.90-V.94	Water transport accidents
V.95-V.97	Air and space transport accident
V.98-V.99	Other and unspecified transport accidents

Source: http://apps.who.int/classifications/apps/icd/icd10online/

Appendix 2-Table-5: Other external causes related injuries ICD-10 codes

W.00-W.19	Falls
W.20-W.49	Exposure to inanimate mechanical forces
W.50-W.64	Exposure to animate mechanical forces

Source: http://apps.who.int/classifications/apps/icd/icd10online/

Appendix 3 Data extraction form (Dental trauma study)

Outcomes Assessment of Pulpal/Nonsurgical Root Canal Therapy Among Traumatised Permanent Anterior Teeth

DATA EXTRACTION FORM

Part 1: COVERSHEET

File /case number:	Trauma category 1st: 2nd :
	Treatment type: 1st: 2nd :
NOTES:	

Part 2: PATIENT DEMOGRAPHICS

1. Patient's Date of Birth:_ _ / _ _ / _ _ _ _ 2. Age group: @ trauma time 0 ☐ 6 - 8 yrs 1 ☐ 9 - 11 yrs 2 ☐ 12 – 14 yrs 3☐ 15 – 17 yrs	4. Patient's Gender: 1☐ Male 0☐ Female

Part 3: Clinical Data

4. Tooth identification:	13 12 11 | 21 22 23 43 42 41 | 31 32 33
5. Date of trauma	_ _ / _ _ / _ _ _ _
6. Cause of trauma	1☐ Falls 2☐ Sport Accident 3☐ Road Traffic Accident 4☐ Assault 5☐ Cyclist 6☐ Hard Biting 7☐ Others → Specify ( ). 0☐ Not Specified
7. Site (place) of trauma	1☐ House 2☐ School 3☐ Park 4☐ Street 5☐ Work 6☐ Others → Specify ( ). 0☐ Not Specified.
8. Number of injured teeth in the same occasion	1☐ One 2☐ Two 3☐ Three or more.
10. Time relapse until receiving the 1st assessment treatment	1☐ up to 4hrs 2☐ >4hrs -24hrs 3☐ 1 -2 Day Later 4☐ 3Days – 1Week Later 5☐ 1weeks – 4Weeks Later 6☐ 1Month – 3Months Later 7☐ 3Months – 6Months Later 8☐ 6Months & Longer 0☐ Not Specified
11. Was the trauma combined with loss or fracture of alveolar bone?	1☐ Yes 2☐ No 0☐ Not cited
12. Was the trauma combined with soft tissue trauma?	1☐ Yes 2☐ No 0☐ Not cited
13. Tooth movement following trauma	☐ Yes → Grade1 ☐ 1,2 ☐ 2,3 ☐ 3 4☐ No 5☐ Avulsion case 0☐ Not cited

14. Trauma classification:	1☐ Enamel (E)fracture 2☐ E &dentine (D) fracture 3☐ E & D with pulp exposure 4☐ Crown- root fracture ☐ Root fracture 5 ☐ coronal 1/3 6 ☐ middle 1/3 7 ☐ apical 1/3 8 ☐ not cited 9 ☐ Concussion 10 ☐ Subluxation 11☐ Extrusion 12☐ Lateral Luxation ☐ M, ☐ D, ☐ P/L, ☐ B. 13☐ Intrusion 14☐ Avulsion → ☐ EADT 1 ☐ <1hr 2 ☐ 1- 2hrs 3 ☐2-3hrs 4 ☐>3-4&> 5 ☐not avulsion case 6☐Not specified. 7☐tooth lost ☐ Extra Alveolar Time 'EAT'. 1 ☐< 1hr 2 ☐ 1- 2hrs 3 ☐2-3hrs 4 ☐>3hrs 5 ☐not avulsion case ☐ Storage Medium. 0 ☐ not specified 1 ☐ Milk 2 ☐ Saliva 3 ☐ Saline 4 ☐ Tap water 5 ☐ Dry paper 6☐ others 7☐not avulsion case 15☐ Enamel dentine fracture with pulp exposure + crown root fracture 16☐ Complicated Crown- root fracture + concussion. 17☐ Avulsion + Enamel dentine fracture with pulp exposure. 18☐ Concussion 19☐ Subluxation + ED# 21☐ Avulsion + Enamel dentine fracture
15. Antibiotic therapy	1☐ Yes ☐Before treatment ☐after treatment. 2☐ No 0☐ not cited
16. Type of fixation (Splint)	0☐ None 1☐ Composite/wire 2☐ Adhesive 3☐ Foil/cement 4☐ Blow down 5☐ Acrylic 6☐ Others → Specify ( ).
17. Fixation period	0☐ None 1☐ < 2 wks 2☐ 2-3 wks 3☐ 4-6 wks 4☐ >6 wks 5☐ Not cited.

18. Mobility after splinting	☐ Yes→ Grade1 ☐ 1,2 ☐ 2, 3 ☐ 3 4☐ No 0☐ Not cited.
19. Type of pulpal/root treatment	0☐ no pulpal/root treatment 1☐ IDPC 2☐ DPC 3☐ Pulpotomy 4☐ Pulpectomy 5☐ Root dressing (Apexification) 6☐ RCT
20. Time relapse until receiving the 1st pulpal/root treatment (since trauma).	1☐ Same day 2☐ 1 -2 Day Later 3☐ 3Days – 1Week Later 4☐ 1week – 4Weeks Later 5☐ 1Month – 3Months Later 6☐ 3Months – 6Months Later 7☐ 6Months – 1Year Later 8☐ 1Year – 2 years Later 9☐ 2Year & Longer 0☐ Not Specified
21. Operator experience (who is done pulpal/root treatment).	1☐ Undergrad student 2☐ Graduate residents 3☐ Postgrad student 4☐ Staff clinicians 5☐ Endodontists 0☐ Not cited 6☐ 1+4
22. Stage of root formation	1☐ ¼ (Divergent) 2☐ 2/4(Parallel) 3☐ 3/4 (Convergent) 4☐ 4/4 (completely formed but apex still open). 5☐ 4/4 (completely formed). 0☐ Not Specified
23. Type of pulpal/canal dressing (s) used	0☐ Not Specified 1☐ none 2☐ NS-$Ca(OH)_2$ 3☐ MTA 4☐ Ledermix 5☐ Others 6☐Ledermix then NS $Ca(OH)_2$
24.Number of changes of pulpal/canal dressing	0☐ Not Specified 1☐ 1 time 2☐ 2 times 3☐ 3-5 times 4☐ 5 & more
25. Mobility recorded after dressing	☐ Yes→ Grade2 ☐ 1, 3☐ 2, 4☐ 3 1☐ No 0☐ Not cited
26. Quality of Temporary Filling	1☐ Good sealing (in place) 2☐ Not good (TF loosed>1time) 0☐ Not cited
27. Root canal after dressing	1☐ Dry and clean 2☐ Pus (or any sign of infection) 0☐ Not cited
28. Root filling material	1☐ Gutta-percha 2☐ Silver cones 3☐ Paste mixture

	4☐ Others → Specify ( ). 5☐ not RCT case. 0☐ None.
29. Obturation length	1☐ Over-filled (>2mm long) 2☐ Under filled (>2mm short) 3☐ Optimally filled (0.5-2mm from root apex) 4☐ Flush filled (on the root apex). 0☐ not RCT case.
30. Quality of filling (presence of voids in root filling)	0☐ None radiographically 1☐ Apical 1/3 2☐ Middle 1/3 3☐ Coronal 1/3 4☐ not RCT case.
31. Type of final restoration	0☐ None 1☐ Temporary restoration ☐ Inter-coronal restoration 2☐ Composite 3☐ Others → Specify ( ). 4☐ Crown 5☐ Others → Specify ( ).
32. Post placement	1☐ Yes 0☐ No
33. Use of subject tooth as an abutment	0☐ None 1☐ Fixed prosthesis 2☐ Removable prosthesis 3☐ Orthodontic treatment. 4☐ Others.
34. Treatment assessment	0☐ failure (short and long-term) 1☐ short-term success and long-term failure 3☐ success of treatment
Comments (should include final treatment assessment):	
51. In case of treatment failure	0☐ no failure 1☐ tooth extracted only 2☐ tooth extracted + implant 3☐ tooth extracted + Fixed prosthodontics 4☐ tooth extracted + Removable prosthodontics 5☐ root kept + over denture For further treatment (preserve bone). 6☐ Others
52. Drop-out : 0☐ None. 1☐ immediate after 1st assessment 2☐ after the start of treatment 3☐ after completion of the treatment	
Questions and reminders:	

Appendix 4 Data extraction form (Dental avulsion study)

DATA EXTRACTION FORM

Part 1: Patient Demographics

Case ID number:	Hospital number:
1. Patient's Gender 0☐ Female 1☐ Male	
4. Patient DOB: / /	
2. Post code:	3. Distance to GDHS: miles

Part 2: Clinical Data

5. Tooth identification (FDI system):	13 12 11 | 21 22 23 43 42 41 | 31 32 33
6. Date of trauma	__/__/____
7. Cause of trauma	1☐ Falls 2☐ Sport Accident 3☐ Road Traffic Accident 4☐ Assault 5☐ Cyclist 6☐ Others → Specify .... 0☐ Not Specified
8. Site (place) of trauma	1☐ House 2☐ School 3☐ Park 4☐ Street 5☐ Work 6☐ Others → Specify .... 0☐ Not Specified.
9. Number of injured teeth on the same occasion	1☐ One 2☐ Two 3☐ Three or more.
10. Was the trauma combined with loss or fracture of alveolar bone?	1☐ Yes 2☐ No 0☐ Not cited
11. Trauma classification:	1☐Avulsion only. 2☐ Avulsion + Enamel (E) fracture. 3☐ Avulsion + E &Dentine (D) fracture. 4☐ Avulsion + E & D with pulp exposure.
12. Extra Alveolar Dry Time 'EADT'	( ) In mins
13. Storage medium	0 ☐ Not specified 1 ☐ Milk 2 ☐ Saliva 3 ☐ Saline 4 ☐ Water 5 ☐ Dry 6 ☐ others ....

14. Previous restoration (prior to trauma).	1☐ Yes→ Specify .... 2☐ No 0☐ Not cited
15. Antibiotic therapy	☐ Yes→ 1☐Before treatment. 2☐after treatment. 3☐ No
16. Contamination	1☐ Washed off. 2☐ Rubbed off. 3☐ Not completely clean. 0☐ Not cited.
17. Stage of root formation	1☐ 1/4 (Divergent) 2☐ 2/4 (Parallel) 3☐ 3/4 (Convergent) 4☐ 4/4 (Completely formed/apex still open). 5☐ 4/4 (completely formed).
18. Type of fixation (Splint).	0☐ No (None) ***GO TO NO (22)*** 1☐ Composite/wire 2☐ Adhesive 3☐ Foil/cement 4☐ Acrylic 5☐ Others → Specify ....
19. Fixation period	( ) days.
20. Mobility after splinting	☐ Yes→ Grade: 1 ☐ Grade 1 2 ☐ Grade 2 3 ☐ Grade 3 4☐ No 0☐ Not cited.
21. Time elapse until pulp removed	☐ ( ) years, ( ) months & ( ) days. ☐ No pulpal/RCT provided. ***GO TO NO (30)***
22. Type of pulpal/canal dressing (s) used	0☐ None 1☐ NS-$Ca(OH)_2$ 2☐ Ledermix 3☐ Ledermix then NS $Ca(OH)_2$ 4☐ Others ....
23. Mobility recorded after dressing	☐ Yes→ Grade: 1 ☐ Grade 1 2 ☐ Grade 2 3 ☐ Grade 3 4☐ No 0☐ Not cited
24. Quality of Temporary Filling (TF)	1☐ Good sealing (in place) 2☐ Not good (TF loosed>1time) 0☐ Not cited
25. Root canal after dressing	1☐ Dry and clean 2☐ Pus (or any sign of infection) 0☐ Not cited
26. Root filling material	1☐ Gutta-percha 2☐ Past mixture 3☐ MTA 4☐ Others → Specify .... 0☐ None.

27. Obturation length	**1☐ Over-filled (>2mm long)** **2☐ Under filled (>2mm short)** **3☐ Optimally filled (0.5-2mm from root apex)** **4☐ Flush filled (on the root apex).** **0☐ not RCT case.**
28. Quality of root canal filling (presence of voids in root filling)	**1☐ Apical 1/3** **2☐ Middle 1/3** **3☐ Coronal 1/3** **4☐ Not RCT case.** **0☐ None radiographically**
29. Root resorption	**1☐ Yes→ (Date: / /** **(=days post replantation).** **2☐ No**
30. Type of root resorption	**0☐ None.** **1☐ Surface.** **2☐ Inflammatory.** **3☐ Replacement.**
31. Resorption index (0-12 Anderson index)	( )
32. Progress in resorption	**0☐ No** **1☐ Yes**
33. Outcomes assessment	**0☐ F-Success** **1☐ Failure)**
34. Number of visits (since trauma).	( )
35. Date of last review	_ _/ _ _/ _ _ _ _