In vitro comparison study of four surgical techniques used in open reduction of hip dislocations in the dog.

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Summary

This dissertation includes a broad literature review on coxofemoral dislocations in small animals, with particular emphasis on the canine patient. It begins with an anatomic description of the hip joint. The aetiology, classification, biomechanics and incidence of the disease are referenced. The pathology, clinical features and diagnosis are also presented. A chapter dealing with treatment develops references of both closed and open reduction (including the surgical approaches), as well as the postoperative management. The literature review concludes with a chapter on the prognosis of each mode of treatment.

The aim of this project was to compare the lateral resistance to reluxation, in cadaver material, between a control group, consisting of the normal hip dissected of all soft tissues other than the intact joint capsule and teres ligament, and four surgical methods of stabilization: (i) Capsulorrhaphy; (ii) Transarticular pin; (iii) Dorsal capsular prosthesis; (iv) Toggle pin. Any one of the above techniques was used on the contralateral dissected hip which was dislocated by a circumferential incision of the joint capsule and transection of the teres ligament.

The hypothesis of the project was that techniques that are very successful clinically, differ in resistance and some have considerably lower resistance than the normal intact supporting soft tissue structures of the joint.

Twenty skeletally mature cadavers of dogs, free from osteoarthritic changes to the hip joint, were used in this study, making up for forty specimens: 10 control specimens of the right hip, 10 control of the left hip, and 5 for each of the surgical groups.

The specimens were tested for peak load at failure using a Instron testing machine, model 4505, which ran, using a series IX cyclic testing software, at a constant rate of displacement of 10 mm / min. and recording a sampling rate of 10 points / second. A load displacement curve was computer generated for each specimen. Failure was defined as occurring when a peak load was followed by a drop of over 20%. The mode of failure was recorded for each specimen.

A statistical analysis of variance (one-way ANOVA) was used to compare the results of peak load at failure between the: (i) Four surgical groups; (ii) Four surgical groups and the control group; (iii) Control group of the right hip and the control group of the left hip. Differences with a probability value < 0.05 were considered statistically significant.

Transarticular pinning was considered significantly weaker than the other three surgical techniques. The combined control group (right and left hip) was considered significantly stronger than the mean value for the four surgical techniques. There were no significant differences between the control groups of the right and left hips.

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Dedication

To my parents, Maria Eduarda and José Manuel, for their constant support, friendship and love.

To my partner, Willow, for correcting my spelling and, most of all, for her love, understanding and everlasting confidence and solidarity throughout this enterprise.

Declaration

I, José Manuel da Mota Cardoso, do hereby declare that the work carried out in this thesis is original, was carried out by myself or with due acknowledgement, and has not been presented for the award of a degree at any other University.

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1. Literature Review

1.1. Introduction

The hip joint is classified as a synovial type joint (diarthrosis). Although flexion and extension are the chief movements of the joint, its ball and socket construction allows a great range of movement (Evans and Christensen, 1979). Like all synovial joints, it has a joint cavity, joint capsule, synovial fluid, and articular cartilage (Brinker, Piermattei and Flo, 1990).

Animal joints are subject to many types of injury of varying degrees of severity. The mildest injury is a simple sprain of the associated ligaments and/or joint capsule with no displacement of the articular surfaces. In more severe injuries the articular surfaces are displaced from their normal positions. If there is no contact between the surfaces, the joint is said to be luxated or completely dislocated. If there is some contact between articular surfaces, the joint is said to be subluxated or incompletely dislocated (Pond, 1971).

Dislocation and luxation are synonymous terms used to describe the displacement of one or more bones of a joint from their normal position. Luxations can be further classified into acute or chronic, depending on the duration of the injury, or as closed or open, depending on whether external contamination has occurred (Eaton-Wells and Whittick, 1990). Slocum and Devine (1990[a]), describing the pathomechanics of hip dysplasia, defended the concept that the term dislocation is most appropriately reserved for the femoral head being out of the acetabulum and outside of the joint capsule.

Dislocations of the hip, the most common traumatic luxation in the dog and cat, are usually due to a direct blow or catching the limb in the top of a fence or gate as the animal attempts to jump the obstacle (Pond, 1975).

The majority of coxofemoral luxations in dogs respond to external manipulation and closed reduction, followed by external fixation with bandages or splints. However, in cases with major soft tissue damage and in long standing cases this treatment often results in reluxation of the joint (Mehl, 1988).

A great number of surgical techniques have been described for canine coxofemoral luxations. These include internal reduction alone (Fry, 1974), capsulorrhaphy with trochanteric transposition (De Angelis and Prata, 1973;

Hammer, 1980), placement of a prosthesis for the teres ligament (Knowles and others, 1953; Lawson, 1965; Zakiewicz, 1967; Denny and Minter, 1973), extension of the acetabular rim with bone grafts or implants (Dalton, 1953; Durr, 1957; Dobbelaar, 1963; Helper and Schiller, 1963; Marvich, 1972; Fuller, 1972), transverse pinning of the femur to the pelvis either above the acetabulum (Horne, 1971) or through it (Gendreau and Rouse, 1975; Bennett and Duff, 1980), placement of an ischioilial pin over the joint (De Vita, 1952; Leeds and Renegar, 1979), purse string sutures (Hansmeyer, 1963; Thompson, 1968), reinforcing the joint capsule using fascia lata (Zaslow and Hanson, 1975), and an extra capsular suture technique (Leighton, 1985; Allen and Chambers, 1986; Johnson and Braden, 1987). Total hip replacement (Hoefle, 1974), excision arthroplasty (Spreull, 1961; Rex, 1963; Piermattei, 1965[a]; Hofmeyr, 1966; De Angelis and Hohn, 1968; Duff, 1975; Gendreau and Cawley, 1977) and triple pelvic osteotomy (Slocum and Devine, 1986) are other alternatives that have been described.

The many methods, described in the literature, of stabilization following open reduction reflect the lack of consistently good results by any one method (Alexander, 1982).

1.2. Anatomy of the Coxofemoral Joint

1.2.1. The Hip Joint

The hip joint is a rather complex ball and socket joint in which a hemispherical femoral head fits into an ellipsoid acetabular socket within the pelvic bone (Evans and Christensen, 1979). Bennett (1990) classified the diarthrosis of the hip joint as an enarthrosis, or ball and socket joint, which permits flexion, extension, abduction, adduction and rotation. Smith, Biery and Gregor (1990) stated that the hip is not a true ball and socket joint because, besides its three degrees of freedom, rotating about three orthogonal axis, it has an extra movement of lateral translation of the femoral head from the acetabulum.

The femoral head forms a cap for the femoral neck. Articular cartilage covers most of the femoral head. The fovea capitis is a depressed area on the caudomedial aspect of the femoral head that is devoid of articular cartilage. The fovea is the point of attachment for the ligament of the head of the femur, also known as the teres ligament or round ligament. This ligament (which is not round) is short and flat, and it extends from the fovea to the acetabular fossa of the acetabulum, where it blends with the periosteum and the transverse acetabular ligament (Manley, 1993).

Most authors (Nunamaker, 1985; Manley, 1993; Wadsworth, 1993) consider the teres ligament to be an important structure in the stability of the hip joint, although Evans and Christensen (1979) described it as being up to 1.5 cm long and 5 mm wide in large dogs and, hence, may allow for variable movement of the head, and Alexander (1982) stated that it does not provide much stability to the joint. Wadsworth (1993) considers the ball and socket configuration in itself as the major stabilising feature of this joint; the teres ligament and the joint capsule being the major soft tissue structures preventing luxation.

Riser (1975) studied the growth and development of the hip joint, and found that the ilium, ischium, pubis, and the acetabular bone fused between the 12th and 14th postnatal week to form a socket that continues to develop in response to the presence of the femoral head. Slocum and Devine (1990[a]) consider the plastic nature of the acetabulum to be caused by the growth plates of the ilium, ischium, and pubis coming together around the acetabular bone.

The proximal femur includes the head, the neck, and three trochanters. Manley (1993) stated that the neck is the continuation of the femoral diaphysis, and its length is controlled by endochondral growth of the capital growth plate. Riser (1975) described the angle formed at the intersection between the femoral neck axis and the femoral shaft, as viewed from a ventrodorsal radiograph, the *angle of inclination,* as having a mean of 135°. The angle between the plane of the femoral condyles and the axis of the femoral neck is the torsion or declination angle. In dogs, the axis of the femoral neck normally projects cranial to the transcondylar plane, and such positive angle is called the *anteversion angle*. Similarly, if the axis projects caudally, the angle of torsion is negative and called *retroversion angle*. The normal angle ranges from +12° to +40°. The importance of the angle of femoral torsion in the development of canine hip dysplasia is controversial. Some reports suggest that femoral torsion increases in dysplastic dogs, as it does in humans affected with congenital hip dysplasia, but it is not clear whether these increases are primary or secondary to hip dysplasia (Manley, 1993).

Manley (1993) described the lunate surface as the horse-shoe shaped portion of the acetabulum normally covered by articular cartilage. A prominent buttress of bone reinforces the dorsal and cranial aspect of the lunate surface and it accommodates the normally high craniodorsal stresses. The acetabular fossa is a thin, depressed nonarticular area at the centre, that serves as a point of attachment for the teres ligament. The transverse acetabular ligament is a fibrocartilaginous ligament that is located at the ventral aspect of the acetabular fossa and it extends across the open end of the acetabular fossa to embrace the ventral aspect of the femoral head. The acetabular labrum is the continuation of this ligament as a fibrocartilage annulus attached to the periphery of the acetabulum. These fibrocartilage structures effectively increase the depth of the acetabulum and the circular stability of the hip joint.

The coxofemoral joint is surrounded by a thin, fibrous joint capsule that is connected to the femur at the base of the neck and at the acetabulum just around the acetabular lip. The acetabulum, a cotyloid lunate cavity, represents the concave portion of the coxofemoral joint and is created by the fusion of the ends of three bones: ilium, pubis, ischium. These encircle a fourth bone, the acetabular bone (Nunamaker, 1985). Cranially, the entire femoral neck is covered by capsule. Dorsally, the capsule extends along the transverse line. Caudally, the trochanteric crest and a portion of the femoral neck remain extracapsular (Manley, 1993).

Riser (1975) stated that the stability of the canine hip joint is governed by the congruency of the articular surfaces between femoral head and acetabulum, the integrity of the joint capsule, ligamentum teres and cartilaginous labrum, combined with the overall strength and mass of the pelvic musculature. Normal integrity of these structures combined with adequate pelvic muscle strength allows complete range of motion during ambulation, or palpation, without allowing subluxation to occur (Chalman and Butler, 1985).

The fit of the femoral head within the acetabulum can be estimated from a ventrodorsal radiograph of the pelvis by measuring the *Norberg angle*, defined by a line connecting the centres of the femoral heads and a second line from the centres of the femoral heads to the cranial effective acetabular rims. An angle less than 105° indicates displacement of the femoral head relative to the acetabulum and implies hip dysplasia (Manley, 1993).

Nunamaker (1985) and Manley (1993) both stressed the importance of the muscle groups that surround the hip joint for support, stability, and locomotion. Slocum and Devine (1990[a]) stated that the muscle and weight bearing forces generated parallel with the long axis of the femur, create no subluxation as long as the acetabulum has sufficient dorsal coverage of the femoral head, and the muscles are balanced so that the adductors do not overpower the abductors. Rettenmaier and Constantinescu (1991) stressed the fact that the hip is the only joint in which muscle action is necessary to prevent luxation during weight bearing. A strong, balanced muscle support is necessary for proper hip joint congruity.

Lust and others (1980) advocated that an increased volume of synovial fluid in the hip joint is one biomechanical component of joint instability and subluxation. The hip joint appears to be an air-tight system, and the capsule and ligament have permissive roles which allow for malalignment when the synovial fluid volume is increased.

Smith and others (1990) considered that the magnitude of lateral displacement of the femoral head is apparently limited by a hydrostatic stability factor. This factor results from a suction or vacuum effect within the joint when the femoral head is laterally displaced. The periarticular musculature, by virtue of their fluid-like mass and resistance to displacement, contributes to the hydrostatic constraint by transmission of a continuous pressure gradient from the sub atmospheric pressure in the synovial fluid to the atmospheric pressure outside the dog.

1.2.2. Muscles of the Hip

The muscles of the hip are grouped according to function. <u>The flexors</u> of the hip include the iliopsoas, the tensor fascia lata, the articularis coxae, the rectus femoris and the sartorius muscles. <u>The extensors</u> of the hip provide the largest muscle mass in the hip and include the gluteals, piriformis, quadratus femoris, biceps femoris, semitendinosus, semimembranosus, gracilis, and adductor muscles. The external rotators include the internal obturator, external obturator, gemelli, quadratus femoris, and iliopsoas. The internal rotators and abductors of the femur include the gluteal muscles and tensor fascia lata. The adductors of the femur include the adductor longus, adductor magnus et brevis, pectineus, and gracilis muscles (Evans and Christensen, 1979).

1.2.3. Vascular Supply

Vascular supply to the dog's coxofemoral joint can be subdivided into vessels that transport blood to the proximal femur and acetabulum (extraosseous vascular supply); vessels that penetrate bone to supply the endosteum, cancellous and cortical bone of the proximal femur and acetabulum (intraosseous vascular supply); and extraosseous vessels that are within the articular capsule of the coxofemoral joint (intracapsular vascular supply), being subsynovial in location (Kaderly, Anderson and Anderson, 1983).

The blood supply to the hip joint and associated musculature in the dog is provided by vessels that originate from the lateral circumflex femoral, medial circumflex femoral, and caudal gluteal arteries. These vessels give origin to the ascending epiphyseal (cervical) arteries, which are divided into four groups: **(i)** cranial cervical ascending vessels, **(ii)** dorsal cervical ascending vessels, **(iii)** ventral cervical ascending vessels, and **(iv)** caudal cervical ascending vessels (Hulse, 1983). The lateral circumflex femoral artery gives rise to the dorsal and cranial portion of the extraosseous ring, the medial circumflex femoral artery gives rise to the ventral and caudal portion, and the caudal gluteal artery gives rise to a small portion near the trochanteric fossa. The arteries of the extracapsular ring pierce the joint capsule and give rise to a series of ascending cervical arteries (retinacular arteries), which ascend the femoral neck within the synovial reflection of the joint capsule (Rivera, Abdelbaki, Titkemeyer and Hulse, 1979; Kaderly, Anderson and Anderson, 1983).

These ascending arteries cross over the periphery of the capital growth plate and enter the femoral head as the epiphyseal arteries. The dorsal and ventral epiphyseal arteries form an intraosseous arcade to supply the femoral head (and the proliferative zone of the capital growth plate in immature dogs). Although an arterial supply is evident within the ligament of the head of the femur, it supplies little of the femoral epiphysis (Rivera and others, 1979; Kaderly and others, 1983) but, in the adult dog with closed epiphyseal plates, it appears that nutrient supply to the femoral head may be in part through the teres ligament as well as through penetration of the epiphysis by vessels that originate from the nutrient artery of the femur (Nunamaker, 1985), thus becoming the metaphyseal artery to the proximal femur and femoral neck.

Hulse, Abdelbaki and Wilson (1981), reporting on the results of a study to investigate the blood supply to the femoral head, following the fixation by a compression screw of surgically induced femoral capital growth plate fractures, showed that a complete revascularisation of the femoral head (in eight dogs less than five months old) was essentially completed by the end of 3 weeks postoperative; the vascular response was derived through re-establishment of the ascending cervical arteries and metaphyseal arteries and the vessels of the teres ligament did not contribute to the revascularisation process in any dog.

In immature animals, before the closure of the capital growth plate, no communication exists between the epiphyseal and the metaphyseal circulation. The femoral head of younger animals is supplied by epiphyseal vessels alone, which arise from the extracapsular ring, which should be preserved as much as possible during exposure of the hip joint (Hulse, 1983; Kaderly and others, 1983).

1.2.4. Innervation

Evans and Christensen (1979) described the lumbosacral trunk as the largest and most important part of the lumbosacral plexus, (derived largely from the cord segments L_4 - S_2), since it is continued outside the pelvis as the sciatic nerve. The lumbosacral trunk arises primarily from the sixth and seventh lumbar nerves with a small contribution from the first and, occasionally, the second sacral nerves. The lumbosacral trunk has two medium-sized branches, the cranial and caudal gluteal nerves. It becomes the sciatic nerve after the last sacral branch enters it at the greater ischiatic foramen.

The sciatic nerve is the largest nerve in the body. It is a continuation of the lumbosacral trunk, and the extra pelvic part of the trunk is regarded as the sciatic nerve. It consists of two nerves, the tibial and fibular (peroneal), which are so closely bound together, proximally, that they appear as one (Evans and Christensen, 1979). The sciatic nerve passes caudally over the hip, medial to the greater trochanter and then distally, caudal to the femur on the lateral side of the adductor muscle. A branch leaves the nerve at the level of the hip and enervates the biceps femoris, semitendinosus and semimembranosus muscles. The sciatic nerve terminates in the thigh as the common peroneal and tibial nerves (Evans and De Lahunta, 1988).

Sharp (1989) stated that the sciatic nerve enervates the most caudally situated muscle group on the thigh - the hamstring group. These muscles serve to flex the stifle joint and, together with the gluteal group which is enervated by the gluteal nerves, to extend the hip joint. At the level of the stifle joint the sciatic nerve then divides into peroneal and tibial branches. The peroneal nerve is the cranial branch which enervates the skin and the muscle groups on the craniolateral surface of the tibia and foot. It therefore activates the hock flexor muscle group and the digital extensors. The tibial nerve branches caudally and enervates the skin and the muscle groups on the caudal aspect of the tibia and foot. It therefore activates the hock extensors and the digital flexors.

1.3. Aetiology, Classification, Biomechanics and Incidence of Hip Luxations

1.3.1. Aetiology

Bruere (1961) and Pond (1975) stated that, in working dogs, being caught in a fence when jumping could cause dislocation of the hip, by a sudden excessive tension on the hind limb, although most cases were caused by severe pressure on the limb, as happens in a glancing blow from a fast moving vehicle.

Coxofemoral luxations in dogs and cats are generally the result of external trauma. Kolata, Kraut and Johnston (1974) reported that, out of 1000 dogs and cats admitted to a Trauma Emergency Service, most cases (48.2%) resulted from road traffic accidents, but this percentage is probably higher because 159 cases (15.9%) were recorded of unknown cause. Approximately 75% of the cases fell into three aetiologic categories: motor vehicle accidents, unknown cause, and animal interaction. The occurrence of these injuries was probably related to the management of the pet and could likely be reduced by appropriate changes in management.

Shuttleworth (1950) stated that, following a road traffic accident, dogs showed a greater incidence of hind limb damage compared with fore limb and head. It may be that, in the panic of finding itself trapped, the dog manages to extricate his fore end, but cannot deal also with the hind quarters. The explanation may lie, also, in the different anatomy of the extremities: the foreleg is relatively mobile; its trunk attachments are completely muscular, the shoulder joint lacking in restrictive ligaments, so that the limb can be twisted quite severely without suffering damage and spring back to its normal position when released, in contrast with the hind limbs.

Formston and Knight (1942) considered the susceptibility of the hip joint to the effects of trauma to be due to the absence of supporting ligaments and to the stresses, strains and antagonistic muscle contractions in the varied movements permitted by this joint.

Stead (1970) reported that 97% of the hip luxations in his study, were caused by the animals being struck by motor cars. Denny and Minter (1973) reported that 66.7% (10/15 cases) of a series of hip luxations were caused by road traffic accidents and 26.7% were of unknown aetiology. Fry (1974) found vehicular trauma to be the cause of 83% of dislocations of the hip, in a study involving 15 dogs and 3 cats. Duff and Bennett (1982) reported that 63% of canine and 59% of feline cases of hip luxation were caused by road traffic accidents. Bone, Walker and Cantwell (1984) found a figure of 83% in a study of 133 hip luxations in dogs where the aetiology was known, whereas Basher, Walter and Newton (1986), reviewing 95 cases of coxofemoral luxation in dogs and cats, found that at least 59% were caused by vehicular trauma, and probably more, with 21% of the animals having incurred traumatic injuries in an unknown incident. Johnson and Braden (1987) reported that 15 of 21 cases (71.4%) with hip luxation were due to automobile trauma, and Meij, Hazewinkel and Nap (1992) reported a figure of 82%.

Pettit (1971) and Olds (1975) reported that ventral luxations could be created by overenthusiastic attempts at reduction of a craniodorsal luxation. Thacher and Schrader (1985), however, qualify this statement, by applying it only to cranioventral luxations. They reviewed 14 cases of dogs with caudoventral hip luxation. 50% of the cases were caused by a fall, whereas road traffic accident was responsible for 28.6% of these caudoventral dislocations. The authors believe that the caudoventral hip luxation is a specific entity with different pathophysiology and clinical signs, which is consistent with a report by Harari, Smith and Rauch (1984) who described 2 cases of caudoventral hip luxation secondary to pelvic vehicular trauma in dogs.

Herron (1986) described six atraumatic ventral luxations in dogs and proposed that these dogs may have been predisposed to the problem due to an abnormal acetabular-femoral head relationship, possibly due to a deficiency in the transacetabular ligament.

Harari, Smith and Rauch (1984) reported two cases of caudoventral hip luxation in young dogs (5 and 11 months old) due to a road traffic accident. In both of these cases, caudoventral displacement of the femoral head was accompanied by separation of the greater trochanter from the femur.

Coxofemoral luxation can also occur as a result of severe hip dysplasia or Legg-Calvé-Perthes disease. The plastic nature of the acetabulum allows for its formation around the femoral head, due to the latter pressing into the acetabulum. There are two characteristics that favour the formation of a deep acetabulum: a small femoral head and a long biomechanic femoral neck, defined as the distance between the centre of the femoral head and the point that is the resultant of internal and external rotator forces applied to the greater trochanter (Slocum and Devine, 1990[a]).

The formation of the acetabulum is complete at 4 months. Slocum and Devine (1990[a]) stated that abnormal changes in the acetabulum prior to this age are the result of the soft nature of the pelvis and the unbalanced direction and magnitude of hip forces. The cartilaginous labrum is incapable of supporting the femoral head when the acetabulum is too shallow and this leads primarily to fracture or deformation of the dorsal acetabular rim. Consequently, the acetabulum forms a cup with no dorsal support. The femoral head moves dorsally until it is constrained by the teres ligament and the joint capsule, which both hypertrophy. The centre of the acetabulum begins to fill with osteophytes as the femoral head subluxates.

Riser (1975) advocated that, after 4 months of age, subluxation may occur because of a dysplastic acetabulum, femoral head anteversion, a shortened femoral neck, an imbalance of adductor and abductor muscle forces, genu valgum, valgus of the femoral diaphysis, excessive weight, fatigue, or neurologic weakness of the pelvic muscles.

The muscle and weight bearing forces generated parallel with the long axis of the femur, create no subluxation as long as the acetabulum has sufficient dorsal coverage of the femoral head, and the muscles are balanced so that the adductors do not overpower the abductors. In the normal hip, there is rotation about the flexion/extension axis, the abduction/adduction axis, and internal/external axis, but there is no translation along these axes (subluxation). The normal hip has both stability and congruency. When forces are applied across the joint, there is a relatively large area of surface contact (approximately 2.5 cm^2), easily capable of absorbing and distributing the loads applied. As hip stability is lost and the femoral head subluxates, congruency is lost. This results in the femoral head transmitting all of the femoral forces to a small area of the dorsal acetabular rim, the breakdown products from this traumatic interaction creating the familiar radiographic changes we know as osteoarthritis. Chronic subluxation causes gradual stretching of the joint capsule. When the subluxated hip can no longer be voluntarily reduced by the patient, then the femoral head will remain out of the acetabulum, yet within the joint capsule. This is called a luxated hip. Once a hip is luxated, the joint capsule begins to accomodate the hip in the new position, rapid degenerative joint disease of traumatic origin occurring (Slocum and Devine, 1990[a]).

1.3.2. Classification

Coxofemoral luxations are usually classified according to the relationship that the femoral head bears to the acetabulum following dislocation (Leonard, 1985). Different authors use a slightly different nomenclature when it comes to classifying the coxofemoral luxations (Nunamaker, 1985; Leonard, 1985; Eaton-Wells and Whittick, 1990; Brinker and others, 1990; Manley, 1993):

(i) Craniodorsal luxation. The femoral head rests dorsal and cranial to the acetabulum, on the shaft of the ilium.

(ii) Caudodorsal luxation. In this case, the head of the femur rests caudal and dorsal to the acetabulum, resting on the ischial shaft, and there is some risk of sciatic nerve injury.

(iii) Cranioventral luxation. These are usually associated with craniodorsal dislocations that have been reduced unsuccessfully into the cranial ventral position.

(iv) Caudoventral luxation. Not uncommonly these are accompanied by fracture of the greater trochanter, with displacement of the femoral head into the obturator foramen.

(v) Intrapelvic luxation. This is incorrectly named because it actually involves an acetabular articular fracture with impaction of the femoral head.

Stader (1939, 1955) classifies the dislocations of the hip, according to the type of treatment necessary to reduce them and to keep them reduced until healing has progressed sufficiently so that they will remain reduced, into three types:

Type 1: Cases of recent origin; when reduced, snap into place easily; not easily redislocated; they require no further treatment.

Type 2: Cases of recent origin; easily reduced but without snapping; have a tendency to redislocate easily with some rotation of the limb; they require a moderate degree of fixation, such as a figure of 8 bandage.

Type 3: Cases which repeatedly redislocate; difficult to determine when reduction has been accomplished; they require maximum fixation.

1.3.3. Biomechanics of the Coxofemoral Luxation

Wadsworth (1993) defined biomechanics as the science of the action of forces, internal and external, on the living body. Any force or set of forces acting on the appendicular skeleton of the animal is transmitted along the limb and may result in any one or a combination of the following injuries: bone fracture, ligament rupture, tendon tear, capsular tissue avulsion, physis separation in young animals, or joint luxation.

Riser (1975) stated that the laws that control bone and soft tissue dynamics control the development of the hip. Newton's law of neutral forces when applied to biological tissues, means that a joint is in functional equilibrium when all forces upon that joint mutually neutralise each other both in intensity and direction. Wolff's law introduces the concept of bone transformation in that changes in function of a bone are attended by alterations in its internal structure.

Arnoczky and Torzilli (1981) designed a theoretical model with which to evaluate the forces acting upon the canine hip joint and to analyse factors which may alter these forces. They found that, during a 3-legged stance the single weight-bearing hip was subjected to a force approximately 1.5 times the body weight, and subluxation of the femoral head causes an increase in the body weight moment about the femoral head, by increasing the distance between the femoral head and the centre of the body. As the femoral head moves away from the centre of the body, the abductor muscle force must increase to maintain balance. This, in turn, results in an increase in the force acting at the hip.

Smith and others (1963) showed that the angles of retroversion or anteversion of the femoral head had no influence on the tendency to luxate. Hammer (1980) reported on a series of 10 cases, which reluxated after closed reduction, that had angles of inclination that were within normal limits, which suggests that recurrent luxation occurs irrespective of these values.

Prieur (1980) studied the normal and abnormal biomechanics of the canine hip joint. He stated that the magnitude of the pressure on the joint surface is the result of the amount and the direction of the force, and the amount of joint surface involved. Damage to the joint will result from an increase in the forces acting upon the joint, a decrease in the joint surface area, and a change in the direction of the forces applied. According to the gait and the moment in time of the step, the force generated by the hind limb acting on the hip varies from a value from zero to several (3 to 4) times that of the body weight.

Smith and others (1990) proved that by adding fluid into the joint capsule allowed equilibration of pressure and negated the fluid-dynamic constraint, thereby resulting in lateral translation of the femoral head, producing aberrant joint mechanics and high joint stresses during weight-bearing, due to hip joint laxity.

(i) Craniodorsal luxation: Schroeder (1936) and Dobbelaar (1963) stated that an indirect force exerted upon the femur during adduction and extension of the leg is the usual cause of craniodorsal luxation of the hip. This force occurs when a leg is extended, as in jumping or falling, and the weight suddenly shifts so that the centre of gravity is lateral to the hip (Leonard, 1985).

Wadsworth (1993) explained that one of the most common causes of luxation of the hip is a strong blow delivered to the rump of the animal. As the hip moves ventrolaterally toward the ground, the long lever action of the adducted femoral shaft draws the femoral head out of the acetabulum as far as the teres ligament and the joint capsule allow. When the greater trochanter strikes the ground, the energy of the blow is transmitted through the femoral neck to the femoral head. The femoral head is driven over the dorsal rim, shearing the joint capsule and the teres ligament. The femoral head comes to rest in its most common position of luxation craniodorsal to the acetabulum. The strong pull of the gluteal muscles also helps to pull the femoral head to this position.

Wadsworth (1993) described another common way for the hip to luxate in a craniodorsal direction, when the body is driven ventrally while the hind leg is extended and abducted as the pelvis moves toward the ground. As the pelvis is forced ventrally, the stifle and hip begin to flex. The stifle makes the initial contact with the ground and, as the pelvis continuous to move ventrally, the hip begins to rotate externally. The femoral head rotates out of the acetabulum as the ligamentum teres and the joint capsule are torn. As in the previous situation, the pull of the gluteal muscles causes the femoral head to move in a craniodorsal direction in relationship to the acetabulum.

(ii) Ventral luxation: Wadsworth (1993) stated that the biomechanics are the same for the cranioventral and caudoventral luxations, except for the position of the femoral head as it is being forced ventrally under the acetabulum. If the leg rotates inward as the hip is luxating ventrally, the femoral head ends up in the obturator foramen. If the leg rotates outward, the femoral head ends up in front of the pubis.

Thacher and Schrader (1985) suggested that the caudoventral hip luxation occurs when the leg is abducted forcibly with the stifle and the tarsus extended and the limb rotated internally. When load is applied with the hip abducted, the femoral head is levered ventrally across or through the transverse acetabular ligament and becomes trapped ventral to the ischial body within the obturator foramen. The gluteal muscles abduct and rotate the limb internally as they are stretched ventrally and caudally.

According to Wadsworth (1993), those ventral luxations that occur naturally are usually associated with the trauma of jumping or falling and landing with the leg abducted. As the leg continues to abduct, eventually the femoral neck and the greater trochanter strike the dorsal aspect of the acetabulum. This forces the femoral head out of the acetabulum, rupturing the teres ligament and ventral joint capsule.

According to Dobbelaar (1963), when abduction or flexion of the leg at the hip joint has occurred during a traffic accident, this usually will result in a fracture of the neck of the femur. A medial dislocation, which is associated with a fracture of the pelvis, would only occur when a direct lateral force is exerted. Harari and others (1984) described 2 cases of caudoventral hip luxation in young dogs, accompanied by separation of the greater trochanter physis, due to vehicular trauma. In both cases, the femoral head was displaced to a position ventral to the ischium, near the obturator foramen (caudoventral displacement), probably due to the pull of the adductor and quadratus femoral muscles.

1.3.4. Incidence

Smith and others (1963) stated that, in humans, the congenital dislocation of the hip is more frequent in females than in males; the left side is more commonly involved than the right side; and it is a rare condition among black people.

It is likely that many injured animals are not admitted for medical attention because the owner believes the injury is not serious, the animal is injured and dies before the owner is aware of its injury, or the animal dies before the owner is able to seek medical attention (Kolata and others, 1974).

Schroeder (1936), reporting on a survey of 1200 cases of fractures and dislocations resulting from various causes, found that injuries in the region of the hip represented approximately 15% of the total, and that approximately 80% of this total were represented by coxofemoral luxations. The coxofemoral joint is the most commonly luxated joint in the dog and cat (Herron, 1979; Leonard, 1985), representing from 50% to 90% of all traumatic luxations in the dog (Fry, 1974; Alexander, 1982; Piermattei, 1982). Each hip is equally liable to sustain luxation (Duff and Bennett, 1982).

1.3.4.1 According to the type of luxation

Hohn and others (1969) stated that craniodorsal luxations account for 85% to 90% of all hip luxations, 2% to 3% are cranioventral, 5% to 10% are central (associated with acetabular fracture), and that caudoventral and caudodorsal are extremely rare. Fry (1974) reported 18 cases out of 19 (94.7%) which had craniodorsal luxations, 5.3% being caudoventral. Harari and others (1984) surveyed

133 pelvic trauma cases over a nine year period, and found only 2 cases of caudoventral luxation. Bone and others (1984) reported 169 (95.5%) luxations as craniodorsal, 6 (3.4%) as cranioventral, 1 (0.6%) as caudoventral and 1 (0.6%) as ventral. Thacher and Schrader (1985), reviewing a seven year period, found 242 dogs with craniodorsal luxations (93.4%), 14 caudoventral (5.4%), 2 cranioventral (0.8%) and 1 caudodorsal (0.4%) luxation.

Perez-Aparicio and Fjeld (1993) recorded, in a retrospective study, 79 coxofemoral luxations in cats. 98.7% of the cases were craniodorsal luxations and only 1 case was displaced ventrally. All of them were unilateral luxations.

Basher and others (1986), described the unilateral craniodorsal luxation as being the most common one (78.1% of dogs and 72.7% of cats), although the canine value should be higher because the direction of luxation was not recorded in 11 patients. Bilateral luxations were infrequent occurrences, accounting for only 4 of the 84 dogs (5.9%) and 1 cat out of 11 (9.1%). Denny and Minter (1973) reported only 6.7% (1/15) of bilateral hip luxations. Duff and Bennett (1982) reported 3.1% (4/129) of dogs with bilateral hip luxation, while in 13 cats only unilateral luxation was recorded, and Bone and others (1984) described an incidence of bilateral luxations of 3.4% (6/177). Meij and others (1992) reported 3 bilateral luxations (17.6%) in a series of 14 dogs and 3 cats, and 15 (88.2%) were craniodorsal luxations.

1.3.4.2 According to age

Kolata and others (1974) found, in their survey about the patterns of trauma in urban dogs and cats, that the median age was 1.9 years for dogs and 1.3 years among cats, which might be related to the supposition that young animals learn to cope with the hazards of their environment through experience, therefore being at greater risk of injury.

Dobbelaar (1963) stated that fractures of the neck of the femur are more common and dislocations less common in young animals under twelve months. However, four of eighteen patients (22.2%) described by Fry (1974) were under twelve months. Bennett (1975) reported 15.7% of cats with craniodorsal hip luxation as being under 1 year of age. Herron (1979) stated that coxofemoral luxations in small animals may be considered the most common problem resulting from pelvic trauma in patients over one year of age, animals under one year being more prone to fractures of the femoral head epiphysis or of the acetabulum. Bone and others (1984) described only 8.8% of dogs with dislocation of the hip as being less than one year of age, which is consistent with the results obtained by other authors. Basher and others (1986) reported that only 7 of 84 (8.3%) of the dogs were younger than one year, and Meij and others (1992) described only one case of seventeen (5.9%) which was under one year old. Perez-Aparicio and Fjeld (1993) stated that 15% of the cats were under 12 months old, the maximum incidence of luxations having occurred from one to three years of age (61%), coinciding with one of their most active, but still inexperienced, periods.

The lower incidence of coxofemoral luxation in dogs younger than one year reflects the fact that the femoral capital epiphysis fuses to the femoral neck between 11 and 12 months of age and that, before this time trauma to this area is more likely to cause a femoral capital physeal separation (Smith, 1960).

Smith (1960) reported the time of fusion of the proximal femoral epiphysis in dogs to occur around the eleventh month. Riser (1975) stated that this growth plate disappears radiographically between 11 and 14 months of age.

According to Salter and Harris (1963), separation through the physis is related to the weakness of the physis in the zone of hypertrophied cells, and its susceptibility to the displacement secondary to avulsion forces. Hulse (1983) advocated that trauma that causes ligamentous injury in the adult is likely to result in a fracture line extending through the zone of cell hypertrophy of the growth plate in the young patient.

The capital growth plate fracture is seen more commonly than other types of femoral neck fractures in the young animal (Hulse and others, 1981). Campbell, Lawson and Wyburn (1965) stated that the ratio of probability that the femoral neck will fracture rather than the hip dislocate in young dogs was approximately 2:1 (38 dogs out of 44 in which fracture of the femoral neck was diagnosed were under one year old). Bennett (1975), reporting on a series of 15 femoral neck fractures and 5 epiphyseal separations in cats, stated that only 4 (all femoral neck fractures) were over one year old.

Separations of the capital physis and neck fractures are most frequently found in 4 to 6 month old dogs and cats. Thus, the femoral neck fracture is typically an injury occurring at the onset of physeal closure and not, as in humans, at an advanced age resulting predominantly from osteoporotic changes (Eaton-Wells and others, 1990).

1.3.4.3 According to breed

Bone and others (1984) reported that the breeds with the largest number of dogs with hip luxations were the breeds with the largest hospital presentations for all diagnosis (German Shepherds, Poodles and mixed breeds). However, poor hip conformation is a possible explanation for the higher number of luxations in the German Shepherds; unstable hips are frequently found in toy breeds, which could explain the higher frequency of luxation in Poodles; increased susceptibility to trauma in dogs allowed to run free could explain the increased frequency in mixed breed dogs. Thacher and Schrader (1985) stated that no breed predisposition was noted in their review of 14 caudoventral luxations, although 28.6% (4/14) consisted of Poodles.

Basher and others (1986) described in their report of 11 cats with hip luxation, that they were all domestic short and long hair breeds. 36% of 84 dogs were mixed breed, while the Doberman Pinscher, German Shepherd, and Labrador Retriever each accounted for 6% of the total number, and the miniature Poodle accounted for 10.7%, which is consistent with the figures shown previously. Perez-Aparicio and Fjeld (1993) stated that, apart from 2 Persians, 77 of 79 cats (97.5%) were ordinary Norwegian crossbreed.

1.3.4.4 According to sex

Denny and Minter (1973) described a sex ratio of 12 males (80%) to 3 females. Kolata and others (1974) reported that injured males of either species (65.4% of dogs and 69% of cats) were significantly more frequent than were injured females, largely because males were admitted commonly for road traffic accident, animal interaction and injury of unknown cause, which supports the opinion that males are more aggressive and tend to wander more than females.

Bennett (1975) stated that 67.2% (43 of 64) of cats which suffered trauma to the pelvic region were males. Duff and Bennett (1982), reporting on a survey which included 129 dogs and 13 cats with hip luxation, indicated that in both cats and dogs 59% of hip luxations were in males. Bone and others (1984) reported that 56% of all hip dislocations were male. Basher and others (1986) stated that 56% of the dogs were intact males and 2.4% were neutered males, and of the cats, 36.6% were intact males and 36.6% neutered males, and Meij and others (1992) reported 64.3% of the dogs and 66.7% of the cats as being males. Perez-Aparicio and Fjeld (1993) recorded a male to female ratio of 51:24; the sex was not recorded in four of the cats.

1.3.4.5 According to species

Kolata and others (1974), reporting on the difference in ratio of dogs to cats in the trauma emergency service population (87.1% dogs / 12.9% cats) when compared with the general hospital population (82.9% dogs / 17.1% cats), attributed this difference to be the result of one or more factors: The local pet population might not include as many cats as the general hospital population, which was based on a referral practice; local cat owners might not seek medical attention for their injured cats, or perhaps cats were not injured as frequently as dogs. The frequency of trauma in the hospital population probably does not reflect the true incidence of trauma in urban dogs and cats.

1.4. Pathology

Dislocations result in obvious mechanical dysfunction. Normal nourishment and lubrication of the articular cartilage are lacking, and weight-bearing on incongruent surfaces leads to further traumatic injury to the cartilage surfaces (Brinker and others, 1990).

Pond (1971), reporting on the structure and functions of the normal synovial joint tissues and their reaction to injury, assessed the osteoarthritic changes which develop in animals, after trauma of some degree has been inflicted on the joint. The following tissue changes were present:

1. Degeneration of the articular cartilage.
2. Inflammation of the synovial membrane.
3. Alteration of the synovial fluid.
4. Inflammation of the joint capsule.
5. Damage to intra-articular structures.
6. Production of osteophytes.

Eaton-Wells and Whittick (1990) stated that since the integrity of a joint depends largely on soft tissue structures, most luxations and subluxations of traumatic origin involve concomitant soft tissue disruption. The resulting luxation or subluxation will result in a degree of concomitant trauma to joint structures that depends on the following: **(i)** The magnitude of the force (i.e., speed, weight); **(ii)** The direction of the force; **(iii)** The posture and position of the animal at the instant of the application of the force; **(iv)** The conformation of the animal; **(v)** The status (age) of the epiphyseal growth plates; **(vi)** Metabolic status of the animal; **(vii)** Presence of pre-existing disease.

Newton (1981) advocated that traumatic arthritis, as an entity, probably was of little concern, but for the fact that it leads to degenerative joint disease. Trauma may incite synovitis or chondrocyte death with resultant protein release, or may change a joint biomechanically. Any one factor or all can lead to degenerative joint disease.

Hulse (1983) stated that trauma causing a coxofemoral luxation results in failure of the ligament of the head of the femur. In the majority of patients, the failure is within the ligament itself, but occasionally, a bone-ligament failure occurs. In such a case, a piece of bone from the ligament insertion on the femoral head is avulsed. The size of the bone chip is variable, but must be removed surgically along with the remnants of the ligament. The avulsed piece of bone originates from a non-weight-bearing surface, and its removal does not result in degenerative joint disease.

Tomlinson (1990) stated that the severity of tissue damage associated with hip luxations varies. In all luxations, the teres ligament and part of the joint capsule are torn. In more severe cases, part of the gluteal musculature also may be torn. Small avulsion fractures of the femoral head, where the teres ligament attaches, are common. Erosion of the cartilage of the femoral head sometimes results from the femoral head's rubbing on the ilium, especially in more chronic cases. On rare occasions, portions of the dorsal rim of the acetabulum are fractured off.

Dobbelaar (1963) stated that, in craniodorsal dislocations of the hip, the articular surfaces themselves usually are not damaged, with the exception of the anterior margin of the acetabulum.

In chronic luxations, the craniodorsal area of the acetabular rim typically is torn away, exposing the bone, a lesion which is often associated with previous ineffective coxofemoral reductions (Leighton, 1985).

Whatever the direction of the luxation, the muscles in the immediate vicinity are damaged and are a source of haemorrhage, as is the blood vessel from the teres ligament, this blood filling the acetabular fossa in conjunction with remnants of the teres ligament and fragments of the joint capsule and, occasionally, avulsed pieces of the femoral head. The contents of the acetabulum gradually form a fibrinous mass which may interfere with attempts at closed reduction and the maintenance of reduction (Shuttleworth, 1950; Dobbelaar, 1963; Alexander, 1982; Leonard, 1985). Basher and others (1986) reported damage to the surrounding muscles (vastus lateralis, middle and deep gluteal) in 4 of 37 dogs which underwent open reduction. Other findings at surgery included a shallow acetabulum (3 cases), degenerative joint disease (DJD) in 2 patients, fragments of the femoral head attached to the torn teres ligament (3 patients), flattening of the femoral head (2 patients), and an undisplaced cortical fracture of the greater trochanter in 1 instance.

Dallman and Mann (1981) considered that, in a matter of hours, the muscles in the affected area contract and therefore shorten, which makes reduction of the luxated joint more difficult. Muscle shortening must be overcome to allow the femoral head to be placed in the acetabulum. In a luxation of longer duration, the acetabulum will be shallow due to the presence of a haematoma or fibrous-like material, which reduces the chances of maintaining reduction of the luxation.

Perez-Aparicio and Fjeld (1993), reporting on the follow-up examination of 29 cats (in a retrospective study of 79 untreated hip luxations), described the development of nearthrosis of various degrees located dorsally on the ilium. The degrees of nearthrosis formation were not consistently correlated to the length of the observation times, which might have been due to individual and age dependent variation in osteogenic stimulus to bone remodelling, cats that were immature at the time of injury having developed a nearthrosis radiographically similar to a coxofemoral joint. Other radiological findings included a flattening of the acetabulum or its remodelling related to its lack of normal function, decreased bone density in the proximal femur and reduced diameter of the femoral neck which could be due to altered blood supply related to the injury of the soft tissue structures surrounding the joint. Moreover, modified biomechanical conditions of the leg probably resulted in moderate osteopaenia in the bone.

Nunamaker (1985) advocated that the caudal luxation may cause significant injury to the sciatic nerve as it passes behind the acetabulum and appears over the sciatic notch of the ischium. He proposed that when caudal dislocations occur, open reduction should be considered from the start to avoid doing further damage to the sciatic nerve through closed manipulative reduction.

Sharp (1989) stated that peroneal nerve deficits are much more commonly seen than tibial deficits, the reason being that the fascicles within the tibial division are small and are surrounded by a higher proportion of connective tissue, as opposed to the large fascicles of the peroneal division which have less protecting connective tissue.

Luxations usually compromise the vascular supply to the dog's coxofemoral joint. The degree of compromise depends on the direction and degree of displacement of the proximal femur. Displacements in the usual craniodorsal direction tend to spare the important ascending ramus of the lateral circumflex femoral artery. Vascular compromise to the femoral head from rupture to the ligament of the head of the femur does not occur (Kaderly and others, 1983).

Backgren and Olsson (1961) reported that 14% of coxofemoral luxations observed in dogs were complicated by intra-articular fracture, probably due to the avulsion of a portion of the caput femoris, which is torn off by the ligamentum teres during luxation. Avulsion fractures of the acetabulum occurred concomitantly only in 1.9% of the dogs. Bennett (1975) stated that, of the 19 cases of cats with craniodorsal luxation, 2 showed a small fragment detached from the femoral head and 1 other had a small fracture of the acetabular rim.

The capital growth plate fracture is seen more commonly than other types of femoral neck fractures in the young animal (Formston and Knight, 1942; Shuttleworth, 1950; Hulse and others, 1981). In general, the femoral capital growth plates fractures, in young dogs, have an excellent prognosis for return to normal function with a low incidence of non-union or late segmental collapse (Nunamaker, 1973). This is in sharp contrast to what happens in human orthopaedics, where the incidence of late segmental collapse, occurring most commonly between one and two years postoperatively, is reported to be as high as 33%. The younger person, having a slipped epiphysis, is most likely to demonstrate the most frequent, the most calamitous and most rapid collapse (Johnson and Crothers, 1976).

Bone and others (1984) reported that half of the 171 dogs with hip dislocation had at least one other major traumatic injury that required medical or surgical treatment: 32.2% suffered pelvic trauma (42 pelvic fractures and 13 sacroiliac luxations); 19.3% had rear limb injuries (22 femoral fractures, 3 tibial fractures, 6 stifle injuries and 2 metatarsal fractures); 7.6% (13) suffered thoracic trauma; 6.4% (11) had cranial or vertebral trauma; 12.2% (21) suffered skin, forelimb or abdominal trauma. Basher and others (1986) reviewed the records of 95 patients (84 dogs and 11 cats) which suffered hip dislocation, and found that 38 patients (40%) had associated injuries, which included pneumothorax, pulmonary contusions, and other orthopaedic injuries. 16 animals (16.8%) had concomitant pelvic fractures and 9 (9.8%) had concomitant femoral fractures. Meij and others (1992), reporting on 14 dogs and 3 cats which suffered dislocation of the hip, stated that in 47% of the cases there was additional trauma, namely fracture of the pelvis, femoral head, humerus, mandible, or coccigeal vertebrae, diaphragmatic hernia, and iliosacral and stifle luxation. Perez-Aparicio and Fjeld (1993) stated that, in the 79 cats with coxofemoral dislocation, a total of 41 concomitant injuries had been recorded as fractures of the pelvis (20), fractures of the femur (10) and other traumatic conditions (11).

1.5. Clinical Features and Diagnosis

A thorough orthopaedic and neurologic examination of the animal is required (De Angelis and Prata, 1973).

Diagnosis is readily established and the diagnostic clinical features of the craniodorsal luxation (the most common one), including reduction in length of the leg, reduction in abduction of the thigh and increase in prominence of the great trochanter, have been described by a number of authors (Campbell, Lawson and Wyburn, 1965; Hohn and others, 1969; Pond, 1975).

Schroeder (1933, 1936) described the clinical signs of a craniodorsal luxation as the limb being in a fixed position with the thigh in outward rotation and abduction, causing the limb to appear twisted away from the hip, and the stifle and toes are directed away from the longitudinal plane. Any attempt at manipulation will intensify muscular spasm and severe pain, and the examination should therefore be performed under general anaesthesia.

Dibbell (1934) proposed a "two-thumb" palpation of the femoral heads with the dog on his stomach and the hind legs hanging over the edge of the examining table to demonstrate the dorsal and forward displacement of the femoral head in cranial dislocations, and ventral and backward in caudal dislocations. In cranial luxations the limb is rotated outward and is considerably shorter than the sound one on extension, whereas in caudal luxations the limb is longer than the sound member and is rotated inward.

Schroeder (1936) and Formston and Knight (1942) described other clinical features of the craniodorsal luxation: an increased distance between the tuber ischii and the greater trochanter and an increased prominence of the trochanter on the affected side, which is further increased by abduction of the limb. Abduction of the normal hind limb tends to reduce the prominence.

According to Schroeder (1933), in caudodorsal luxations the limb is adducted and the thigh is rotated inward with the stifle and toes pointing toward the opposite limb, the hip is usually extended and the stifle is flexed. On comparing the length, it will be found that the displaced limb is longer on extension and shorter on flexion, and there is resistance to abduction.

Besides the above mentioned symptoms, Dobbelaar (1963) stressed the importance of palpation. In craniodorsal dislocations the greater trochanter projects above the line drawn from the tuber coxae to the tuber ischii, a symptom which also appears in fractures of the neck of the femur. Under general anaesthesia, movements should be performed with the leg: crepitation is often clearly perceptible; unlike fractures of the neck of the femur, in which abduction is not restricted, dislocations are marked by the fact that this movement is difficult to perform.

Pettit (1971) and Alexander (1982) indicated the three tests which should be performed to help in the diagnosis of coxofemoral luxations:

(i) Palpation of the greater trochanter. This test is best performed with the animal standing. In cases of coxofemoral luxation, the greater trochanter is elevated above an imaginary line drawn from the tuber coxae to the tuber ischii. Elevation of the trochanter is seen in all luxations except the intrapelvic.

(ii) Comparison of the legs for length. This test is performed by placing the animal in dorsal recumbency and extending both limbs by grasping the hocks. The hips are then moved from flexion through full extension. In craniodorsal luxations, the involved limb is longer than the opposite normal limb when the hips are flexed, but becomes comparatively shorter as the coxofemoral joints are extended.

(iii) The trochanter thumb test. In this procedure, the examiner's thumb is placed in the naturally formed depression between the greater trochanter and the ischiatic tuberosity. The limb is then grasped above the stifle and rotated outward. In a normal hip joint, the resulting caudal movement of the greater trochanter displaces the thumb from this depression. Failure to displace the thumb is indicative of coxofemoral luxation.

Leonard (1985) stressed that caution must be exercised in diagnosing a coxofemoral luxation solely on the basis of these tests, because the results will be very similar in cases of femoral head and femoral neck fractures.

Thacher and Schrader (1985) described the findings on physical examination of 14 dogs with <u>caudoventral luxation</u>: they all were non-weight bearing on the affected limb, which was carried in slight abduction and internal rotation with flexion of the stifle; the greater trochanter of the affected femur was displaced medially and more difficult to palpate than that of the opposite side; adduction of the limb and external rotation of the hip were limited by entrapment of the femoral head within the obturator foramen and by the gluteal muscles.

Pettit (1971) stated that, if the patient is able to stand, the position assumed by the injured limb is predictably influenced by the direction of the luxation and is therefore diagnostically useful. Piermattei (1982) stated that, because of the usual history of trauma, the clinical signs are associated with sudden onset, pain, deformity, crepitus, and limited or abnormal movement of the limb. The specific signs vary somewhat, depending on the location of the femoral head in relation to the acetabulum, and can be resumed as follows:

(i) Craniodorsal luxation - The limb is shorter then the opposite limb when extended ventrally or caudally, the thigh is adducted, and the stifle rotated outward and the hock inward. On palpation, the space between the greater trochanter and the tuber ischium is increased and the greater trochanter is elevated when compared to the normal side.

(ii) Caudodorsal luxation - There is a slight increase in the length of the leg when it is extended caudally but a decrease when the leg is extended ventrally. The thigh is abducted, with inward rotation of the stifle and outward rotation of the hock. On palpation, there is a narrowing of the space between the greater trochanter and the tuber ischium as well as an elevation of the greater trochanter.

(iii) Ventral or intrapelvic luxation - The head of the femur rests ventral to the acetabulum and it is very difficult to palpate. There is a definite lengthening of the limb.

Nunamaker (1985) proposed placing the animal in dorsal recumbency and evaluating the height of the tibial tuberosity when the femur is perpendicular to the table and the tibias are held parallel to the table, thus determining the relative position of the hip joint (**Allis sign**).

Ventro-dorsal and lateral radiographs are essential both in verifying the diagnosis and detecting complications, such as fracture separation of the capital femoral physis, fracture of the femoral neck or acetabular fractures (Hohn and others, 1969; Alexander, 1982), or any pelvic injuries that would complicate the treatment (Pettit, 1971; Pond, 1975). Additionally, the presence of dysplasia or Legg-Perthe's disease will generally prevent the closed reduction and stabilisation of a dislocated hip (De Angelis and Prata, 1973; Herron, 1979). An avulsion of the insertion of the teres ligament will not only generally prevent successful closed reduction, but on the rare occasion where closed reduction is successful, the presence of the bone chip will generally create severe degenerative joint disease (Piermattei, 1982; Brinker and others, 1990).

Lust and others (1980) suggested that the standard radiograph with the hip in the antero-posterior, extended position, may alter the orientation of the capsules and muscles from that of the standing position, disguising some cases of subluxation.

Slocum and Devine (1990[b]) devised a dorsal acetabular rim (DAR) radiographic view and positioning, to visualise the weight bearing portion of the acetabulum of dogs for hip evaluation, which enables one to correlate what is viewed on radiographs with characteristics felt on palpation. The acutely luxated femoral head causes a bevel to the rim, characteristic of a torn joint capsule and worn labrum, which correlates with the fine granular crepitus and distinct abrupt dorsal translation of the femoral head felt during palpation.

Wallace (1983) and Fox (1991) advocated that, if the trauma is from a motor vehicle or of unknown origin, radiographs of the thorax are especially important to determine whether pneumothorax, traumatic lung syndrome, diaphragmatic hernia, or rib fracture is present. Bennett (1975) stressed that the presence of other orthopaedic injuries besides those of the pelvic region can greatly prolong the recovery period of the animal or even prevent a complete recovery. In his survey, 26.6% of cases had orthopaedic injuries affecting other regions of the body.

1.6. Treatment

Piermattei (1982) stated that the aims in treatment of this disease are to reduce the dislocation with as little damage to the articular surfaces as possible, and to stabilise the joint sufficiently to allow soft tissue healing with the expectation of normal clinical function.

Dislocations of the hip are normally treated by closed reduction, although an acceptable clinical result can be obtained in some cases which are left untreated, thereby developing a pseudoarthrosis (Bruere, 1961; Campbell, Lawson and Wyburn, 1965; Stead, 1970; Bennett, 1975). Pettit (1971) considered unfortunate that this is called a pseudoarthrosis because "it gives the condition a dignity it does not deserve", the hip remaining painful in most cases, its motion is restricted and the leg is carried or used only for balance.

Various methods have been described to effect reduction of the hip luxation and, once reduction is accomplished, to maintain the hip in position until stabilisation has taken place. In every case of dislocation, it is essential to perform reduction as rapidly as possible, provided the patient's condition allows for a safe anaesthesia (Dobbelaar, 1963; Herron, 1979).

Campbell and others (1965) stated that the longer the hip is left in a luxated position the more change there is likely to be in the femoral head and in the acetabulum which may increase the difficulty of treatment, and the possibility of lameness following satisfactory reduction. Stability may be less easy to establish also as a result of the marked muscle atrophy which occurs in these animals, the gluteal muscles being affected as well as the muscles lower down the limb. When these muscles are weak the tension being exerted to maintain the femoral head within the acetabulum will be much less than normal. Piermattei (1982) claimed that, as time goes by, soft tissue, haematoma, and hypertrophy of the teres ligament within the acetabulum will all block the acetabulum and prevent the femoral head from re-entering on closed reduction. After several days, simple muscle contracture greatly limits the operator's ability to reduce the luxation, particularly in large breeds.

Wallace (1983) proposed that dogs with degenerative joint disease associated with hip dysplasia that sustain a traumatic coxofemoral luxation are generally candidates for an excision of the femoral head and neck or a total hip prosthesis. Tomlinson (1990) advocated that animals with moderate to severe degenerative changes of the hip are not candidates for open or closed reduction, and other methods should be used with such animals.

1.6.1. Closed Reduction

1.6.1.1 Indications

Herron (1979) advocated that the indications for closed management of coxofemoral luxations in the dog and the cat included an animal that had been recently traumatised and that had a luxation of a normal coxofemoral joint. The patient should also be in good clinical condition prior to anaesthesia for radiography to confirm the diagnosis of hip luxation and to evaluate the patient for concurrent hip disease. Basher and others (1986) stated that, despite the high failure rate with closed reduction, it is the procedure of choice upon initial presentation of a patient with coxofemoral luxation if the luxation is not complicated by acetabular fracture, the presence of an avulsion fragment, or failed previous reduction.

Closed reduction is worth attempting as an initial form of treatment even in chronic luxations, but successful relocation may require more than one manipulative reduction (Campbell and others, 1965; Duff and Bennett, 1982; Bone and others, 1984), but Olds (1975) claimed that there is a poorer prognosis for maintaining closed reduction if it is attempted more than four or five days post-trauma. Wallace (1983) stated that the success of closed reduction for luxations of more than 48 hours' duration decreases, owing to the presence of soft tissue in the acetabulum.

1.6.1.2 Contra-indications

Some of the contra-indications for utilisation of closed management of luxation of the hip include the presence of concurrent fractures, the presence of pre-existent hip disease such as hip dysplasia, subluxation, chronic luxation of the normal hip and concurrent acetabular fractures (Herron, 1979).

1.6.1.3 Manipulative closed reduction techniques

Eaton-Wells and Whittick (1990) advocated that, prior to attempting reduction, sustained traction on the limb for a period of 10 minutes may be required to overcome muscle spasm. Selection of the anaesthetic agent should give consideration to agents that induce a high degree of skeletal muscle relaxation so as to reduce muscle spasm and facilitate reduction.

Schroeder (1933) first described the technique of closed reduction of a craniodorsal luxation, with the patient under general anaesthesia. The animal is placed in lateral recumbency with the involved hip uppermost. An assistant holds the pelvis fixed by passing a towel or padded rope around the medial surface of the proximal extremity of the thigh, while the operator grasps the limb, with the stifle flexed, applying axial traction simultaneously with inward rotation, adduction, and flexion of the hip. A characteristic feel of the head slipping into the acetabulum will be experienced. In cases of longer standing it is usually necessary to apply considerable force on the long axis traction for a period of ten to sixty minutes to effect the tearing of adhesions formed in the new position.

Dibbell (1934) proposed a similar technique, but added up a swinging movement of the limb in a complete arc from the hip joint, while the operator's thumb guides the head of the femur into place. In cranial luxations the arc traction is directed counter clockwise in the right hip and clockwise in the left hip, whereas in caudal luxations the arc traction should be directed clockwise in the right hip and counter clockwise in the left hip.

In cases of caudodorsal luxation, Schroeder (1933) recommended applying axial traction, outward rotation, and flexion.

Stader (1936) described the use of a retractor implement which fitted into the patient's groin, and which allowed the application of a steady traction to the affected limb, until the femoral head was positioned in such a way that it would permit, by inward rotation of the femur, the reduction of the luxation.

Ehmer (1948) described the use of a broom handle (slipped under the thigh) as a lever over a brick fulcrum, to lift the femoral head over the acetabular rim while traction was applied to the femur.

Shuttleworth (1950) proposed a method of reduction intended for the most chronic cases, whereby the hip is slowly and gently abducted to the full extent, and then flexed and extended in a similar manner, intended to break down adhesions and overcome muscle spasm. Powerful traction is then applied to the femur in a downward and forward direction trying to direct the femoral head into the acetabular socket. Often, the femoral head will fail to overcome the acetabular rim and will come to rest ventral to the ilial body. In such cases, the greater trochanter should be supported by the thumb and the leg rotated from the abducted position until the femoral head enters the acetabulum from a ventral approach. After reduction, pressure is applied over the trochanter while flexing and extending, abducting and rotating the hip, for a few minutes, in order to squeeze out all debris from inside the acetabulum.

Knight (1956) advocated a simple technique to reduce craniodorsal luxations, using the dog's own weight. Two slip knots, on both ends of a calving rope, are placed above each hock; the dog is next suspended from a hook, the operator grasps the dog and raises it about 20 cm, then dropping it the same distance, thereby reducing the luxation.

Dobbelaar (1963) advocated that, as a rule, the animal should be placed in a lateral position and secured on one side of the table by a cord passed between the hind limbs while, standing on the opposite side of the table, the veterinarian will then be able to exert force upon the leg by pulling, bending and rotating in order to return the head of the femur into the acetabulum.

Campbell and others (1965) advocated a procedure of closed reduction of craniodorsal dislocations, similar to that described by Shuttleworth (1950), that was carried out in two stages. **(i)** The first manipulation consisted of a series of manoeuvres whereby the limb was hyper-abducted and hyper-extended, followed by the application of pressure to the femoral head in a caudal direction by the fingers, and then by the flexion and adduction of the hip while the surgeon attempted to push and roll the femoral head over the cranial acetabular rim. Even though this manipulation will only result in a small proportion of cases, the authors considered it a very useful procedure since it effectively mobilises the hips and eases subsequent manipulation. In immature dogs in which the epiphyses have not yet fused, epiphyseal separation is a likely hazard during reduction and the authors suggested the use of the second type of manipulation. **(ii)** If the preliminary procedure was unsuccessful, moderate traction should be applied in a direction slightly cranial and medial to the normal position of the leg, with the foot rotated inwards. Then, by grasping the limb with both hands around the thigh, the femoral shaft was lifted laterally thus raising the femoral head over the acetabular rim. The surgeon then applied pressure with both thumbs to the greater trochanter, pressing it ventrally and slightly caudally, but at the same time attempting to lift it over the rim of the acetabulum.

Hohn and others (1969) summarised, as follows, the steps of the reduction technique for a craniodorsal luxation, suggesting that if the luxation is any of the other types it should first be manipulated into a craniodorsal luxation: **(i)** Outward rotation of the limb to dislodge the femoral head; **(ii)** Backward down pull; **(iii)** Inward rotation if the head has reached the rim of the acetabulum; **(iv)** Abduction, thus forcing the femoral head into the joint cavity.

Pettit (1971) advocated that, whatever the method of reduction which is employed, planned manipulations replace excessive but ineffective force.

Herron (1979) stressed that, in small dogs and cats, care must be taken that the manipulation and traction do not reduce the femoral head too far and place it into the obturator foramen. Alexander (1982) suggested that ventral and caudal luxations should be converted by the clinician into a craniodorsal position prior to attempting closed reduction, although Thacher and Schrader (1985) did not recommend this, for it is both unnecessary to achieve reduction and may damage the dorsal supporting structures of the joint. Instead, reduction is accomplished by applying traction with one hand (left hand for the left limb, right hand for the right limb), while the other hand applies counter traction against the ischium. The traction hand then applies a levering or lifting action on the proximal femur, which is aided by the thumb of the opposite hand, lifting the femoral head laterally into the acetabulum.

Stader (1936, 1939, 1955) classified three types of coxofemoral luxations into: **(i) Type 1-** Recent cases which are easily reduced, snap into place, and are not easily redislocated. These cases are said to require no further treatment. **(ii) Type 2-** Recent cases, easily reduced but which do not snap on reduction, and which tend to redislocate with some rotation of the limb. These cases require further treatment consisting of bandaging the extremity in extreme flexion (figure of 8 bandage) for about a week. **(iii) Type 3-** Cases which redislocate after reduction, possibly due to severe damage to the acetabulum and filling of the socket, and which require maximum fixation.

Campbell and others (1965), Pettit (1971), Herron (1979) and Alexander (1982) advocated that, immediately after reduction, the coxofemoral joint should be put through a full range of flexion and extension, while maintaining pressure on the greater trochanter, in an attempt to force any blood clots and other soft tissue debris from the acetabulum, thus seating the femoral head and completing the reduction. The joint should then be tested for stability to ascertain the most appropriate supportive measures.

Leonard (1985) advocated that if the femoral head snaps into place with a thud, it usually means that the retaining structures of the joint are not badly damaged. At other times, the head repositions without sound or vibration, in which case the reduction should be regarded with suspicion because it is more likely to reluxate.

Pond (1975) described the complications which might be encountered in the closed management of coxofemoral dislocations as follows. **(i)** Inability to reduce: if there is no radiologically detectable reason, such as fracture of the femoral head or acetabulum, the common cause is organised haemorrhage or soft tissue accumulation in the acetabulum; if forcing the femoral head into the acetabulum is not successful in removing this material, the author then considered open reduction to be necessary. If luxation is complicated by fractures, then open reduction is necessary in order to achieve fixation of the fracture and reduction of the dislocation. If intra-articular fractures cannot be accurately and rigidly fixed, then the femoral head and neck excision should be performed. **(ii)** Inability to maintain reduction by the sling is a good indication for the use of a De Vita pin.

1.6.1.4 Additional procedures to maintain reduction

a) Garbutt (1948) advocated traumatising the tissue surrounding the articulation (bruising of the gluteal muscles after closed reduction) by striking a number of hard blows around the periphery of the joint, using a rubber mallet, in order to produce hyperaemia which will cause the femur to remain in place. Campbell and others (1965) also advocated this procedure, for it produced swelling and pressure on the hip, and also caused spasm and fixation of the muscles, thereby helping to maintain stability in the region.

b) A number of methods have been described in order to ensure that reduction is maintained, by the use of metal pins:

(i) Dalton (1953) and Stader (1955) both advocated the use of a similar technique which consisted of the insertion of pins, into the shaft of the ilium, ischium and greater trochanter, which are clamped to a triangular metal rod. This metal structure holds the femoral head in place for the required time of two weeks, when sufficient healing occurs. However, De Vita (1952) called the attention to the fact that any restraining device, which interferes with free motion of the joint, will give healing which will break down when motion is restored.

Vincent (1961) criticised this technique for its difficulty, and for the fact that the metal structure, which remains outside the skin, causes some discomfort to the animal, can easily be damaged or even torn out, and the pins protruding through the skin encourage infection.

(ii) McLaughlin and Tillson (1994) described the use of an external fixator consisting of two Ellis pins connected by a flexible band intended for maintenance of closed reduction of craniodorsal hip luxations. A first threaded pin was inserted at the dorsal surface of the ilial body, cranial to the acetabulum, directed perpendicular to the spine and exiting the ilial body near the tuberosity for the rectus femoris muscle. A second Ellis pin was inserted into the greater trochanter, entering the femur at the proximal, craniolateral portion of the greater trochanter and exiting caudally and medially, distal to the lesser trochanter. The non threaded ends of the Ellis pins, which remained outside the skin, were then connected by a flexible band, thus exerting a lateral to medial force on the greater trochanter and abducting and internally rotating the femur.

(iii) Durr (1957) described the use of two threaded Kirschner wires inserted over the trochanter major into the bone forming the roof of the acetabulum, passing through the joint, thereby extending the acetabular rim, thus preventing craniodorsal reluxation by exerting ventral pressure on the greater trochanter and the femoral head. The wires were left in place for 12 days.

(iv) De Vita (1952) introduced the use of an ischioilial pin for maintaining reduction. In this method, a Steinmann pin is introduced through a stab incision just ventral to the tuber ischii, while the leg is held in abduction, and directed cranially dorsal to the acetabular rim and into the wing of the ilium, to provide additional support to the dorsal aspect of the coxofemoral joint. The end caudal tip of the pin is then cut just under the skin. In the original report, the patient was immediately ambulatory and the pin was removed after 10 days. De Vita claimed that this technique is also applicable in the cat, even though this species has a very flat lateral pelvic bone which prevents the pin from being inserted into the ilium, but allows it being hooked within the ilium musculature, although Pettit (1971) and Duff and Bennett (1982) considered that this technique could not be usefully employed in feline hip luxations.

Leeds and Renegar (1979) suggested that the ideal indication for this technique was the canine patient with multiple orthopaedic trauma consisting of a dislocated hip and at least one other major orthopaedic problem (long bone fracture, torn ligaments, or where the opposite hemipelvis is fractured). The use of the De Vita pin allows immediate weight bearing, thus protecting the surgical devices applied for the treatment of the other injuries and enabling the patient to walk on the limb while healing around the hip joint takes place. This is particularly important in large and giant breeds which will do poorly if not returned to early weight bearing.

Mechanically the De Vita pin has three separate functions during the healing phase. By extending the dorsal acetabular rim, dorsal and lateral displacement of the femoral head is prevented, thus allowing for active flexion and extension of the hip joint as the dog walks. By holding the hip in place for 4 to 6 weeks the gluteal muscles and joint capsule are allowed to heal and give support to the joint when the pin is removed. By developing a channel of scar tissue around the pin, when the pin is removed, not only have the gluteal muscles and joint capsule healed, but the channel of scar tissue will be providing a permanent reinforcement of the dorsal rim of the acetabulum (Leeds and Renegar, 1979).

Read (1980) stated that an obvious advantage of this technique is that it permits early weight-bearing and mobility of both hindlegs, thus distributing the animal's weight. Early return to function avoids the problems of pressure necrosis, joint stiffness and muscle atrophy which can often result from enforced immobility.

Duff and Bennett (1982) stated that the De Vita pin can only provide a deterrent to dorsal and craniodorsal luxations as the pin acts as a lateral extension to the dorsal acetabulum. Reluxation can occur unimpeded in other directions, however, thus a percentage of relocations are unlikely to be maintained by a De Vita pin.

Alexander (1982) indicated some potential problems associated with the use of the De Vita pin as being the possible pin migration, which may necessitate early removal, and damage to the sciatic nerve during insertion of the pin, although Read (1980) reported one successful case where, by inserting the pin just lateral to the tuber ischii, the distance between the path of the pin and the sciatic nerve was increased, thus lessening the risk of nerve injury. Wallace (1983) suggested that a slow insertion of the pin should be made in order to allow the sciatic nerve to move as the pin advances; if the nerve is touched by the point of the pin it will cause the leg to jerk, in which case the pin should be withdrawn and redirected. Pettit (1971) stated that the most common error in applying the De Vita pin is starting too far medially at the ischium. In the rare instance that a pin should migrate before its planned removal, the pin can be left protruding at the ischium and clamped by Kirschner-Ehmer half-pin splintage to a short anchoring pin inserted nearby in the ischium. Leeds and Renegar (1979) described also the development of a draining tract, which may form underneath the tuber ischii where the pin irritates the skin and which are a potential source of infection, although they generally clear up rapidly when the pin is removed. Pin migration can be prevented by the use of a threaded pin (Leeds and Renegar, 1979) and by cutting a groove in the blunt, caudal end of the pin and suturing it to the tendinous origins of the biceps hamstring muscles (Duff and Bennett, 1982).

Vincent (1961) described a slight modification of De Vita's technique, the main change being that the posterior end of the pin is bent at right angles close to the skin, in order to prevent migration of the pin.

Gendreau and Rouse (1975) indicated the De Vita pinning technique for sub acute luxations and dysplastic dogs, and advocated the use of a large (4.7 mm or 6.2 mm) Steinmann pin introduced slightly lateral and ventral to the ischial tuberosity, anchored in the tendons of origin of the biceps femoris, semimembranous and semitendinous muscles, because if it is placed under the ischium, it tends to lie too medial to prevent lateral movement of the femoral head. The authors stated that, after this procedure, the dog should be allowed to use the leg on a limited basis until the pin is removed in 14 to 20 days.

Nunamaker (1985) advocated that this technique should not be performed as a closed procedure without observation of the sciatic nerve and, since there is also the danger of pin migration, the author does not warrant its use. Eaton-Wells and Whittick (1990) stated that this technique requires open reduction and monitoring of the sciatic nerve.

1.6.2. Open Reduction. Surgical Approaches.

Hohn and others (1969) pointed out the **indications** for open reduction as follows: **(i)** Old luxations where fibrosis prevents a closed reduction; **(ii)** Joint capsule and/or blood clot and fibrinous or fibrous tissue interposition; **(iii)** Osteochondral fracture, usually at the attachment of the teres ligament, which prevents the proper seating of the femoral head in the acetabulum; **(iv)** Cases which will not remain reduced in spite of applied immobilization, due to a shallow acetabulum, destroyed cartilaginous labrum, severe tearing of all surrounding muscular support, or a fracture of the dorsal acetabular rim.

Pettit (1971) claimed that, in luxations that are more than a few hours old, closed reduction may be hampered by granulation tissue proliferating from the stump of the femoral head ligament or by organising adhesions that hold the femoral head in its new position outside the acetabulum.

Leeds and Renegar (1979) and Alexander (1982) considered that the three main indications for surgical treatment of craniodorsal coxofemoral luxations were: avulsion fracture of the femoral head (leaving an intra-articular bone fragment), an unsuccessful or unstable closed reduction, or the need for immediate weight bearing on the surgically reduced hip, whereas Fry (1974) described three main groups where surgery is indicated. **(i)** In the first group are those which are easily reducible but dislocation recurs with equal ease when pressure is applied along the axis of the femur. (ii) The second group comprises those cases which subsequently redislocate after apparent successful manipulation. (iii) In the third group are those where it has not been possible to reduce the dislocation with manipulative techniques.

Nunamaker (1985) advocated that, if success is not achieved readily, open reduction should be considered, since considerable damage can be sustained by the femoral head and surrounding soft tissues if a long time is spent doing closed manipulative manoeuvres. When a caudal dislocation does occur, open reduction should also be considered from the start to avoid doing further damage to the sciatic nerve through closed manipulative reduction.

Tomlinson (1990) stated that the goals of open reduction of a coxofemoral luxation are to re-establish normal function and confirmation of the hip. Once the healing is complete, the anatomic shape of the hip joint and fibrosis of the joint capsule hold the hip in place.

The **choice of the surgical approach** to the hip joint depends on several factors, including the size of the patient (in small dogs a gluteal tenotomy approach may be the most advantageous), the method to be used for stabilisation (Gorman's approach with trochanteric osteotomy allows transposition of the greater trochanter), and the experience of the surgeon (Alexander, 1982). Pettit (1971) claimed that although a specific situation may favour one approach over another, the dorsal approach remained the most versatile for routine use, not only providing the greatest exposure, but also allowing for the application of any fixation device that may be indicated. Tomlinson (1990) advocated the use of the craniolateral approach in acute luxations, and the dorsal approach by osteotomy of the greater trochanter for chronic luxations.

Kaderly and others (1983) stressed the importance of taking into consideration the normal vascular patterns of the mature dog's coxofemoral joint when approaching it surgically. Surgical approaches should involve minimal disruption of the cranial and dorsal aspects of the extracapsular vascular ring, because most of the femoral head and part of the femoral neck are ultimately supplied by these vessels. The above authors suggest the use of the Gorman approach (a properly placed osteotomy of the greater trochanter, lateral to the extracapsular vascular ring), rather than the craniolateral approach that would damage important vessels supplying the extracapsular vascular ring (particularly the ascending ramus of the lateral circumflex femoral artery).

Piermattei (1982) stated that the approach of choice was generally a dorsal or a caudodorsal approach to the hip and may be combined with osteotomy of the greater trochanter. Because the femoral head is most often luxated dorsally and cranially, the cranial approaches do not allow observation of the acetabulum with the femoral head in the luxated position.

1.6.2.1 Craniolateral approach

Archibald, Brown, Nasti and Medway (1953) described an approach to the craniodorsal aspect of the hip through a craniolateral incision. A skin incision is made from the greater trochanter, following the cranial aspect of the femur, to a point just above the stifle. The fascia lata is then cut from the middle of the femoral shaft upward over the greater trochanter. The aponeurosis where the cranial border of the vastus lateralis attaches to the rectus femoris muscle is slit upward to expose the hip joint, care being taken to avoid injury to the femoral nerve, and the femoral artery and vein. The authors claimed that this is the least traumatic approach since it avoids transection of any muscles.

Brown and Rosen (1971) suggested a modification of this technique, by curving the skin incision cranially, on its proximal end, and by incising the common origin of the vastus lateralis and intermedius muscles.

Piermattei (1993) described an approach, based on the procedures of Archibald and others (1953) and Brown and Rosen (1971):

(i) The skin incision is centred at the level of the greater trochanter and lies over the cranial border of the shaft of the femur. Distally, it extends one third to one half of the length of the femur; proximally, it curves slightly cranially to end just short of the dorsal midline.

(ii) An incision is made through the superficial leaf of the fascia lata, along the cranial border of the biceps femoris muscle.

(iii) The biceps femoris muscle is retracted caudally to allow incision in the deep leaf of the fascia lata to free the insertion of the tensor fasciae latae muscle. The incision is then continued proximally through the inter muscular septum between the cranial border of the superficial gluteal muscle and the tensor fasciae latae muscle.

(iv) The fascia lata and the attached tensor fasciae latae muscle are retracted cranially and the biceps caudally. Blunt dissection and separation along the neck of the femur allows visualisation of a triangle bounded dorsally by the middle and deep gluteal muscles, laterally by the vastus lateralis muscle, and medially by the rectus femoris muscle.

(v) The joint capsule, which is covered by areolar tissue, is cleared away by blunt dissection. An incision is then made in the joint capsule and continued laterally along the femoral neck through the origin of the vastus lateralis muscle on the neck and on the lesser trochanter. Exposure can be improved by tenotomy of a portion of the deep gluteal tendon close to the trochanter, leaving enough tendon on the bone to allow suturing.

(vi) The deep gluteal muscle is sutured to its tendon insertion, and the origin of the vastus lateralis muscle is sutured to the cranial edge of the deep gluteal muscle. Continuous sutures are placed in the insertion of the tensor fasciae latae muscle distally and continued proximally along the cranial border of the superficial gluteal muscle. The superficial leaf of the fascia lata distally and the gluteal fascia proximally are closed to the cranial border of the biceps femoris with a continuous pattern. The rest of the area is closed routinely in layers.

Pettit (1971) preferred this approach for excision arthroplasty and considered it a useful one for open reduction of femoral neck and epiphyseal fractures. It can be awkward, however, for reduction of craniodorsal hip luxations because exposure is limited and the luxated femoral head blocks access to the acetabulum.

1.6.2.2 Dorsal approach

Brown (1953[a]) described the dorsal approach to the coxofemoral joint used in installing total hip prostheses. Anderson, Schlotthauer and Janes (1953) described a similar approach to the hip, but with the hip joint being exposed by separation of the fibres of the middle and deep gluteal muscles. Dobbelaar (1963) considered Anderson's technique more attractive than Brown's, the latter presenting great difficulties to suture the muscles together, not to mention the severe haemorrhages resulting from this procedure.

This procedure is also described by Piermattei (1993) and consists of:

(i) A skin incision is centred on the cranial aspect of the greater trochanter of the femur, curving craniomedially to near the midline, and following the cranial border of the femur distally to near mid shaft. Some authors (Hohn and others, 1969, De Angelis and Prata, 1973) prefer a crescent-shaped flap incision. The subcutaneous tissues are reflected with the skin.

(ii) An incision is then made in the superficial leaf of the fascia lata along the cranial border of the biceps femoris muscle for the entire length of the exposure.

(iii) The biceps femoris muscle is retracted caudally and the sciatic nerve identified. An incision is made in the deep leaf of the fascia lata to free the insertion of the tensor fascia latae muscle. This incision is continued proximally along the cranial border of the superficial gluteal muscle. The tendon of insertion of the superficial gluteal muscle is then cut close to the third trochanter, leaving enough tissue to allow suturing.

(iv) The superficial gluteal muscle is retracted proximally to expose the middle gluteal muscle, and the belly of this muscle is undermined near its insertion on the greater trochanter. The middle gluteal muscle is transected at its insertion, taking care to protect the sciatic nerve during these procedures. The freed middle gluteal and attached piriformis muscles are retracted dorsally.

(v) The deep gluteal muscle is then freed from its insertion on the greater trochanter and dissected from the joint capsule.

(vi) After surgery, interrupted sutures are placed in the joint capsule. The tendons of the deep and middle gluteal muscles are re-attached to the trochanter by means of a suture passed through a hole drilled, from lateral to medial, in the dorsal lip of the greater trochanter. Locking-loop or mattress sutures are placed in the tendon of the superficial gluteal muscle, and a continuous layer in the insertion of the tensor fasciae latae muscle. The superficial leaf of the tensor fascia lata distally and the gluteal fascia proximally are closed to the cranial border of the biceps femoris with a continuous pattern.

1.6.2.3 Osteotomy of the greater trochanter

The acetabulum is exposed through what is also known as the **Gorman approach** (Piermattei and Greeley, 1979; Lipowitz, Caywood, Newton and Finch, 1993; Piermattei, 1993). This approach is started as **(i)** to **(iii)** of the dorsal approach, followed by:

(iv) The greater trochanter is osteotomised by placing the osteotome on the lateral surface of the greater trochanter, through the epiphyseal line, at a 45° angle with the long axis of the femur. Alternatively, a Gigli wire can be used. The greater trochanter, with the insertion of the gluteal muscles, is then reflected dorsomedially, exposing the joint capsule.

(v) After surgery, the greater trochanter is attached to its bed by two Kirschner wires or with the tension band wire technique.

Alexander (1982) expressed his preference of the trochanteric osteotomy approach to the coxofemoral joint in dogs greater than 9 kg, because this method allows excellent visualisation and inspection of the acetabulum and the femoral head, provides a strong closure and allows transplantation of the greater trochanter.

1.6.2.4 Caudolateral approach

Piermattei (1993) described this approach to the caudal aspect of the hip joint and body of the ischium, based on a procedure by Slocum and Hohn (1975).

(i) After a curved skin incision had been made centred on the caudal surface of the greater trochanter, starting near the dorsal midline and extending through the proximal one third of the femur, the fascia of the biceps muscle is incised at the cranial border of the muscle.

(ii) The tendinous insertion of the superficial gluteal muscle is cut near its attachment on the third trochanter, and the incision is continued into the deep leaf of the fascia lata. The superficial gluteal muscle is retracted craniodorsally and the biceps femoris caudally to expose the external rotator muscles of the hip.

(iii) With the femur internally rotated, the combined tendon of insertion of the internal obturator and gemelli muscles is cut close to its attachment in the trochanteric fossa. A stay suture in the tendon of the internal obturator and gemelli muscles will help in its retraction, which will also retract and protect the sciatic nerve. This approach provides good exposure of the acetabulum, and can be combined with the Gorman's approach and osteotomy of the greater trochanter.

(iv) During closure, a locking-loop suture is placed in the tendon of the internal obturator and gemelli muscles and then attached to the insertions of the deep and middle gluteal muscles at the trochanter.

Pettit (1971) considered this approach helpful in the removal of an avulsed fragment of the femoral head, since the teres ligament attaches to the caudoventral part of the acetabulum, although exposure of the hip joint is minimal. Denny (1993) preferred this approach because the majority of hip dislocations occur in a craniodorsal direction and consequently the gemelli and internal obturator muscles, which insert on the caudal aspect of the proximal femur, are often torn or stretched over the acetabulum thus providing a ready-made approach. Eaton-Wells and others (1990) suggested this approach, combined with the osteotomy of the greater trochanter, to expose fractures of the acetabular area.

1.6.2.5 Ventral approach

De Angelis and Hohn (1968) described and indicated this approach for excision arthroplasty of the femoral head and neck, and Piermattei (1993) described it as being also indicated for ventral dislocations of the femoral head, as well as ostectomy of the ramus of the pubis for triple pelvic osteotomy:

(i) The patient is positioned in dorsal recumbency with the affected limb in extreme abduction. A skin incision is made directly overlying the pectineus muscle. The incision runs distally along the pectineus for a distance of one third the length of the femur.

(ii) The belly of the pectineus muscle is mobilised by blunt dissection, with care being taken to protect the femoral artery, vein, and saphenous nerve that run along the cranial border of the muscle.

(iii) The pectineus muscle is then transected near its origin on the prepubic tendon and reflected distally to reveal the iliopsoas muscle and the medial circumflex femoral artery and vein that run caudally and medially to the acetabular portion of the pelvis. An interval between the iliopsoas and the adductor longus muscle is developed by blunt dissection, and retraction of the iliopsoas cranially and the adductor caudally exposes the acetabular rim and the ventral aspect of the hip joint capsule.

Pettit (1971) claimed that the ventral approach offered the best cosmetic results because the incision is in a relatively obscure location. Exposure of the acetabular fossa is excellent, but craniodorsal dislocations of the femoral head makes it relatively inaccessible from a ventral incision, and fixation devices to prevent reluxation cannot be applied.

1.6.3. Surgical Techniques

Careful pre-operative radiographic examination of the pelvis should be carried out. The presence of bony abnormalities, such as fractures, arthritis or dysplastic changes in the hip joint, dictate different surgical treatments. During the operative procedure, if the dorsal fibrocartilaginous labrum of the acetabulum is severely damaged or avulsed (not always visualised by radiography), the chances of maintaining reduction are markedly reduced and it is probably best to excise the femoral head and neck rather than proceed with an open reduction (De Angelis and Prata, 1973).

The primary aims of these procedures are to anatomically reduce the luxation and to sufficiently stabilise the coxofemoral joint to allow the patient to return to full function (Alexander, 1982).

Wallace (1983) stated that the method of repair is generally determined by the duration and extent of injury related to the luxation and by the preference of the veterinary surgeon. The veterinary surgeon must be familiar with more than one method because, on occasion, the preferred method cannot be used, and an alternate one must be employed. It is also important to be familiar with the various surgical approaches to the hip for obtaining the best exposure of different classes of luxations.

1.6.3.1 Capsulorrhaphy

Once the coxofemoral joint has been exposed, Leonard (1985) advocated that the acetabulum should be cleansed of all its contents, including the teres ligament. If the joint capsule has been inverted into the acetabulum, it should be gently manipulated from the socket. The dorsal fibrocartilaginous labrum should be inspected for any evidence of fracture. The femoral head is observed for signs of cartilage damage, and remnants of the teres ligament are removed.

Whatever the approach, and whatever the surgical technique which is employed, most authors (Piermattei, 1982; Basher and others, 1986; Lubbe and Verstraete, 1990; Eaton-Wells and Whittick, 1990; Fox, 1991; Meij and others, 1992; Denny, 1993; Manley, 1993) recommended that capsulorrhaphy should be attempted, after reduction of the dislocation, suturing the tears or incisions in the joint capsule with preplaced simple interrupted, horizontal or cross-mattress pattern of absorbable or non absorbable material. Tomlinson (1990) suggested that the leg should be held in abduction during the imbrication to relieve the pressure on the joint capsule.

Hammer (1980) stressed the importance of meticulous restoration of the joint capsule, based on Smith and others (1963) experimental study, which found that a luxation would not occur if the joint capsule, teres ligament, or cartilaginous acetabular rim were separately removed but, if the joint capsule and the teres ligament were both removed, then luxations occurred in a high percentage of the animals. In a number of cases, the joint capsule has been avulsed from the acetabular rim. Successful restoration has been achieved by reattaching the capsule to the acetabular rim with stainless steel sutures placed through holes drilled in the acetabular rim (Hammer, 1980). If holes are used, they must originate as close to the acetabular rim as possible so they do not interfere with the femoral head (Tomlinson, 1990).

Dobbelaar (1963), however, stated that the joint capsule need not be sutured, for it is a striking fact that both the joint capsule and the teres ligament will have healed completely by about two months after the operation, and Fry (1974) found that the damaged state of the joint capsule after dislocation makes it difficult to undertake repair anyway.

1.6.3.2 Trochanteric osteotomy and replacement of the greater trochanter

Hohn and others (1969), De Angelis and Prata (1973), and Hammer (1980) defended the use of this technique as it rotates the femoral head deeper into the acetabulum and abducts the limb due to the normal pull of the gluteal muscles. Allen and Chambers (1986) considered capsulorrhaphy with trochanteric transposition as their procedure of choice: it avoids the potential complications of some other techniques, such as injuries to vital structures (sciatic nerve or organs within the pelvic canal), implant migration, intra-articular foreign body reactions, and direct interference of implants with articular surfaces.

After the joint has been exposed through the Gorman approach, the acetabulum should be cleaned of fibrin, blood clots or any soft tissues that may be blocking it. Haematomas, hypertrophied teres ligaments or fat pads, and muscle fragments are excised, but all joint capsule tissue is preserved. Avulsed bone fragments are removed, except in rare cases where they are large enough to be fixed in place (Brinker, Piermattei and Flo, 1990).

Following reduction, capsulorrhaphy is performed, using relatively heavy-gauge synthetic absorbable or non absorbable simple interrupted mattress sutures (sizes 3 or 4 metric). A new bed for the greater trochanter is then created, with an osteotome, just distal and slightly caudal to the original one. The greater trochanter is re-attached to the femur with two Steinmann pins or Kirchner wires and a tension band wire (De Angelis and Prata, 1973; Alexander, 1982; Lipowitz and others, 1993).

The vastus lateralis cut in the osteotomy is sutured to the superficial gluteal muscle on the greater trochanter, and the remainder of the wound is closed routinely.

According to De Angelis and Prata (1973), it is important to keep the limb in abduction from the time of capsulorrhaphy to the postoperative application of an Ehmer sling, for two to three weeks. The underlying principle of translocation of the greater trochanter is to achieve internal rotation and abduction of the limb by placing the bulk of the gluteal musculature under additional tension, thereby creating an internal Ehmer sling. When the greater trochanter is translocated, exact placement is essential - care must be taken to place it neither too far distally, which will cause overstretching and subsequent fatigue of the gluteal muscles, nor too far caudally, resulting in excessive internal rotation of the limb and impaired ability to walk.

1.6.3.3 Transarticular pin technique

Gendreau and Rouse (1975) were the first to describe this technique, indicated for recurrent or for long standing dislocations. The hip is approached craniolaterally and the acetabulum is cleared of any debris; a small intramedullary pin (1.6 mm to 2.5 mm) is introduced in the fovea capitis and retrograded down the femoral neck until it exits through the lateral surface of the femur and is withdrawn until its tip reaches the surface of the fovea capitis; the dislocation is then reduced, and the pin is driven across the joint space through the medial surface of the acetabular fossa, ventral to the weight bearing surface (lunate surface) of the acetabulum, protruding into the pelvic canal by at least 1 cm; the pin is then cut about 1 cm from the lateral surface of the femur to allow for its removal; the joint capsule is repaired, if possible, and the wound is closed routinely.

Bennett and Duff (1980) advocated the use of the transarticular pin technique for those cases where simple external reduction had failed or where there was some other complicating factor, such as bilateral hip luxation where De Vita pins had failed, long bone fracture complication, and chip fracture of the femoral head causing the joint to easily reluxate after external reduction. The authors described the use of a similar technique, in 6 dogs and 1 cat, with the modification that, after removal of granulation tissue and debris from the acetabulum, a Steinmann pin was inserted in a normograde fashion, using a Jacob's chuck, immediately ventral and lateral to the greater trochanter, and was pushed through the femoral neck and head to emerge through the fovea capitis of the femoral head. The luxation was then reduced, and the pin was pushed through the acetabular fossa until it could be felt emerging through the acetabulum by an assistant performing a rectal examination. The chuck was then used to bend the pin at its free end and the excess length of pin cut off. The surgical wound was routinely closed.

Alexander (1982) stressed the importance that the pin should pass through the fovea capitis of the femoral head and the acetabular fossa because this minimises damage to the weight bearing surface. Wallace (1983) advocated that the size of the Steinmann pin should be of a diameter of 50 to 75% of the diameter of the fovea capitis.

Hunt and Henry (1985) described the technique and the long-term results of transarticular pinning in 40 dogs. The candidates for surgical repair were selected on the basis of one or more of the following criteria: (i) acute traumatic hip dislocation in which reduction could not be achieved or maintained by the use of an Ehmer sling alone; (ii) long-standing (3 days or more) or recurring dislocations; (iii) luxations associated with femoral head fracture; (iv) dislocations associated with acetabular fracture; (v) hip dysplasia or pre-existing degenerative disease of the hip joint. The hip joint was approached craniolaterally, and the acetabulum was cleaned of any debris. With the dislocated hip reduced, the pin (1.6 mm to 3.1 mm, according to body weight) was power driven from the third trochanter into the femoral neck and head, no attempt being made to drive the pin through the fovea capitis. The joint capsule was then sutured (when feasible) and the operative site was closed in a routine manner. Before skin closure, the hip was held in flexion and abduction while the pin was driven, using a handchuck, across the acetabulum, through the medial cortical wall and into the pelvic canal, while an assistant checked the position of the pin tip by palpation per rectum. Finally, the pin was cut and the end was bent over to reduce local tissue trauma, discourage migration, and aid removal.

Aron and Toombs (1984) recommended pre-drilling with a drill bit smaller than the pin, in order to accomplish smooth and precise pin insertion and to limit excessive temperature elevations which cause thermal necrosis. Matthews, Green and Goldstein (1984) stated that pre-drilling is highly effective in minimising both the maximum temperatures and their duration. This technique is recommended for clinical use whenever possible. If pins are to be placed without pre-drilling of the hole, then a pin tip, such as the half-drill design, should be selected allowing for rapid removal of chips to minimise thermal damage to cortical bone.

Egger, Histand, Blass and Powers (1986) determined the effects of various methods of inserting fixation pins into canine cortical bone. Based on the findings of their study, they concluded that high speed power insertion caused an increase in bone necrosis surrounding the pins, due to the high temperatures developed during insertion. Both high speed power and hand drilled inserted pins required less force for pin extraction. Low speed power insertion, hand chuck, and pin placement with a hand chuck after pre-drilling required the same force for pin extraction although, histologically, hand chuck inserted pins caused an increased mechanical damage.

1.6.3.4 Toggle pinning

A more physiological method of supporting the reduced luxation is to insert a prosthetic teres ligament (Bennett and Duff, 1980).

Knowles, Knowles and Knowles (1953) proposed a method of repairing the teres ligament using fascia (or synthetic suture material). A hole was drilled through the neck and head as well as the acetabulum and a piece of ligament, folded double and provided with an iron cross piece, was inserted into this tunnel, using a toggle pin-cannula assembly, the portion of ligament being manoeuvred until this cross piece was situated transversely in front of the hole within the pelvic cavity. The fascia was then drawn tight so that the head of the femur was pushed into the acetabulum and the fascia was secured on the outside of the femur, through a second tunnel drilled cranially to dorsally through the greater trochanter.

Lawson (1965) indicated the use of this procedure especially for recurrent hip dislocations associated with a chip fracture of the dorsal acetabular edge, which causes gross instability of the hip. The hip was exposed through an incision over the lateral aspect of the femoral shaft, just below the third trochanter, the luxation was reduced and, while keeping the hip in a neutral position, a tunnel was drilled up the femoral neck starting from the exposed flat surface immediately distal to the third trochanter, and directed towards the centre of the femoral head. A hand chuck and a trochar pointed 3.1 mm pin were used, which has the advantage of permitting the operator to appreciate by touch if the pin is advancing along the correct line. The total length of pin required to penetrate the fovea capitis should be pre-determined by measurement from a radiograph. The drill pin was withdrawn and the toggle pin was carried on the end of an introducer (a long hypodermic needle with its point removed), and it was displaced from the end of the carrier into the pelvic canal by passing a stylette. Fixation of the ends of the braided nylon prosthetic suture may be done by stitching into the dense fascia of the area, or by using a small second drill hole made through the bone, or by the use of a stainless button.

Denny and Minter (1973) proposed a modification to the previous techniques. The hip joint was approached dorsally by osteotomy of the greater trochanter. Following debridement of the acetabulum a larger tunnel was drilled through the acetabular fossa using a 4.7 mm bit to allow the introduction of the toggle pin (fabricated according to Piermattei, 1965[b]) and prosthesis (one or two strands of 7 metric braided nylon). While the femoral head was still dislocated and the fovea capitis visible, a smaller tunnel was drilled, using a 2.3 mm bit, starting at the third trochanter, through the femoral neck and head, to emerge at the fovea capitis. The prosthesis was then drawn through the femoral head, in a retrograde manner, by means of a wire loop, prior to reduction. A second tunnel was drilled, cranial to caudal, just distal to the site of osteotomy of the greater trochanter. The hip was then reduced and held in abduction while the braided nylon was pulled tight, and after threading one end through the second femoral tunnel using a wire loop the two ends were tied.

Brinker and others (1990) proposed a slight modification to this technique, suggesting that the hole drilled through the femoral head and neck should be started at the fovea capitis and continued laterally to exit the femoral shaft in the region of the third trochanter. The size of the hole should be relatively small (2.8 mm or 4 mm) in order to minimise additional devascularisation of the femoral head. With the hip still luxated, the drill was then used to create a hole in the upper end of the acetabular fossa. The procedure then followed the one described by Denny and Minter (1973), the joint capsule was sutured to the extent possible and the greater trochanter was re-attached with two Kirschner wires or a tension band wire.

Denny (1993) favoured the use of this procedure in both dogs and cats. After a caudal approach, the torn joint capsule is trimmed back and the acetabulum is cleared of haematoma or granulation tissue. When a pseudoarthrosis has formed in a long-standing dislocation, thickened joint capsule must be removed and adhesions between the femoral head and the dorsal acetabular rim broken down before reduction of the dislocation can be achieved. In the cat, the author advocated the construction of the toggle from 18 gauge wire, and the use of Polydioxanone (PDS) or braided nylon as the teres ligament prosthesis.

Advocates of this procedure point out that the prosthetic ligament need not function indefinitely, as healing of the joint capsule and supporting hip muscles eventually occurs. Nevertheless, uncertainty about the length of time the device will last is perhaps the most valid criticism of an otherwise useful procedure (Pettit, 1971).

1.6.3.5 Dorsal capsular prosthesis

This technique, which is also referred to as synthetic capsule technique or as extracapsular suture stabilisation, was first described by Leighton (1985) who indicated it for chronic luxations, when the craniodorsal area of the acetabular rim has been torn away, exposing the bone (often associated with previous ineffective reduction attempts).

(i) The coxofemoral joint is approached either craniolaterally or dorsally. Before the luxation is reduced, the acetabulum is explored and cleared of any tissues that might interfere with the proper seating of the femoral head.

(ii) A short, cortical bone screw is inserted near the dorsal edge of the acetabulum, taking care not to penetrate the joint. A second screw is inserted more cranially, and a third one is inserted in the craniodorsal aspect of the femur, on the femoral neck. The screws are not tightened completely at this time.

(iii) Non-absorbable suture material is looped in a figure of 8 fashion between the screw in the femur and those along the acetabular rim. The suture material loops remain loose enough to allow normal positioning of the coxofemoral joint. To prevent the suture material looped around the screws from becoming detached during activity, separate retaining sutures are tied horizontally around each suture bundle near each screw, then looped securely around the screw. All three screws are then tightened.

Leighton (1985) considered that this technique is contra-indicated in dysplastic joints and when sizeable portions of the femoral head or the acetabular rim are missing. In small dogs, the author advocated that the suture material should be passed through a small hole drilled transversely through the base of the greater trochanter rather than around a bone screw.

Allen and Chambers (1986) described a similar technique, of extracapsular suture stabilisation, indicated for such cases of coxofemoral luxations in which there is extensive damage to the joint capsule and/or a contralateral injury that should be protected from full weight bearing. This technique allows augmentation of the stability of the capsulorrhaphy with trochanteric transposition procedure in coxofemoral luxations in which a secure capsulorrhaphy is not possible or when weight bearing is desirable to protect a contralateral injury.

Allen and Chambers (1986) described the following steps to their procedure:

(i) A dorsal approach to the hip is made by osteotomy of the greater trochanter. The acetabulum is cleared of the remnants of the teres ligament and any debris.

(ii) A transverse tunnel is drilled through the femoral neck just lateral and distal to the joint capsule attachment. Two strands of heavy non absorbable suture material are passed through this tunnel. The luxation is reduced, and the joint capsule is closed with an interrupted horizontal mattress pattern of non absorbable monofilament suture. When capsular damage is extensive, adjacent soft tissues (rectus femoris and gemelli muscles) are incorporated in the capsular sutures to ensure that the joint is covered.

(iii) Two cancellous screws with washers (to prevent the sutures from slipping over the screw head) are placed over the dorsal acetabular rim, 5 to 10 mm from the articular margin, at the 10 and 1 o'clock positions for the left hip, and at the 11 and 2 o'clock positions for the right hip.

(iv) One strand of the femoral suture is then passed around the cranial screw and tightly secured while the limb is held in a normal standing position. The remaining femoral suture is similarly tightened around the caudal screw. Both screws are then tightened.

(v) The greater trochanter is transposed to a more caudal and distal position on the femur with tension band wire fixation and the wound is closed routinely.

Johnson and Braden (1987) proposed a technique which is a compromise between the two previous ones. After a dorsal approach by osteotomy of the greater trochanter, two cortical bone screws are placed in the dorsal acetabular rim and a third screw is placed in the trochanteric fossa of the femur. Heavy non absorbable suture material is placed and securely tied, in figure of 8 fashion, from the acetabular screws to the femoral screw with the limb held in a slightly abducted position.

Miller (1994) stated that the main complication of the dorsal capsular prosthesis technique which can arise, if reluxation occurs, is the femoral head coming to lie on the dorsal screws and thereby being immediately severely damaged.

1.6.3.6 Other Techniques

a) Some methods are **designed to augment the dorsal acetabular rim laterally** (based on the same principle as described by Durr, 1957), since most hip dislocations are of the craniodorsal type:

(i) Helper and Schiller (1963) reported on the use of a new technique whereby, after using the Gorman's approach to the hip joint, the dorsal rim of the acetabulum was extended with some tubular plastic prosthesis, screwed to the dorsal acetabular rim, and extending laterally to a maximum of halfway up the neck of the femur. A splint or cast was not needed for postoperative support.

(ii) Dobbelaar (1963) described a technique by which, after dissecting the acetabulum from soft tissues including the remnants of the teres ligament, reduction is maintained by implanting two 3cm long cortical bone grafts at the site at which the head of the femur has slipped over the margin of the acetabulum when dislocation occurred. These grafts will prevent redislocation of the head of the femur, will not interfere with the performance of movements and will be re-absorbed in due course. By the time the bone grafts have disappeared, both the joint capsule and the teres ligament will have healed completely (the joint capsule need not be sutured, for both the capsule and the teres ligament will have healed completely by about two months after the operation). The site at which the graft was inserted can scarcely be identified within about nine weeks after grafting.

The difficulties which have to be coped with are, in acute dislocations, the symptoms of contusion about the joint causes difficulty in suturing the tissues which tend to tear apart, and in long-standing dislocations (over three weeks duration), the injured region will frequently show a marked growth of connective tissue resisting most attempts at reduction.

(iii) Horne (1971) reported the use of a thread ended Steinmann pin inserted through the greater trochanter, with the femur placed in a slightly abducted position. The pin was directed so that it passed proximal to the head of the femur and entered the acetabular portion of the pelvis on the craniodorsal border of the acetabulum. No attempt was made to close the joint capsule. The pin was removed 10 days postoperatively. The author claimed that the advantages of this technique were that no orthopaedic device remained in the joint, the function of the limb was nearly normal while the reduction was maintained, no external fixation was necessary, and the procedure was relatively easy to perform.

(iv) Fuller (1972) advocated the use of a threaded Steinman pin, inserted perpendicular to the acetabular rim, into a predrilled hole, after using the craniolateral approach to the joint. The pin was left in place for four to five weeks.

(v) Marvich (1972) reported the use of a technique which consisted of the insertion of one or two 3.5mm cortical screws in the dorsal rim of the acetabulum, after having approached the joint through the Gorman's approach. An Ehmer sling was applied (only on large dogs) for three days, but the screws were not removed.

b) Other methods of prosthetic replacement of the teres ligament have been described.

(i) Zakiewicz (1967) described the use of a skin graft for reconstitution of the teres ligament. A piece of skin (0.5 cm in width) was prepared from the edge of the wound, and one of its ends was doubled and sutured to make a knot. After the tunnel had been drilled, a loop of steel was passed up the tunnel, and when it was felt by the fingers, forceps were introduced and the loop was drawn from the depth of the wound. The free end of skin graft was then inserted into the wire loop and carefully drawn through the tunnel until the knotted end locked itself on the medial cortex of the acetabulum. The free end of skin was secured to the femur with thin wire threaded through a small hole drilled across the bone below the greater trochanter.

(ii) Lubbe and Verstraete (1990) reported the use of a transarticular loop of autogenous fascia lata to stabilise the coxofemoral joint following open reduction of recurrent and long standing hip luxation in 10 dogs and 2 cats. The caudolateral approach to the hip joint was used and a strip of fascia lata was harvested. A tunnel was hand-drilled through the acetabular fossa and a femoral tunnel was drilled from the fovea capitis to the third trochanter. A double strand of orthopaedic wire was bent into the shape of a graft passer and its hook portion was passed through the acetabular tunnel and manipulated so as to appear over the ischium, under the sciatic nerve. One end of the harvested fascia lata strip was then hooked into the graft passer and, with a retrograde manoeuvre, was pulled through the acetabular tunnel. Using a wire loop, the fascia strip was then threaded through the femoral tunnel, the dislocation was reduced, and the two ends of the fascial strip were overlapped, tensed and sutured together.

c) A technique of anchoring the femoral head within the acetabulum by means of a **transarticular screw** was described by Garbutt (1948). After a lateral approach over the greater trochanter, a hole was drilled lateral to medial, from the greater trochanter, through the femoral neck and femoral head and through the acetabulum, and a metal screw was inserted. The screw was removed at the end of twelve days.

d) Hansmeyer (1963) and MacDonald (1964) described a technique which consisted of the placement of a **purse string suture** in the muscles around the greater trochanter, thus tightening the muscle forces around the hip, after a skin incision had been made directly over the greater trochanter. Suture passage around the greater trochanter must be made carefully in order to avoid the sciatic nerve. A modification of this procedure was described by Thompson (1968).

e) Fry (1974) advocated the use of good muscle repair to ensure maintenance of the reduction. The surgical approach to the hip joint was as described by Brown (1953a) with gluteal myotomy. No attempt was made to repair the joint capsule but, after reduction of the dislocation, the author used sutures in a figure of eight pattern to repair each individual layer of the gluteal muscles to ensure that the muscle mass firmly enclosed the joint. The author postulated that the surgery of the gluteal muscles equates to the physical bruising and the suturing technique corresponds to the strapping of the limb. This technique was considered not suitable for dislocations resulting from hip dysplasia, in which case if surgery was indicated then excision arthroplasty would be performed.

f) Zaslow and Hanson (1975) described the use of a **fascia lata transplant** in selected cases in which the joint capsule had been damaged to a point where normal capsulorrhaphy became impossible. After a dorsal (Gorman's) approach to the hip, the strip of fascia lata was carried cranial to the hip joint, passed under the belly of the rectus femoris muscle, over the femoral neck, under the belly of the gemelli muscle, and pulled into place.

g) Slocum and Devine (1987), Tomlinson (1990) and Meij and others (1992) advocated the use of an **extra-articular stabilization** technique. A hole was drilled, dorsal to ventral, at the attachment of the rectus femoris muscle in the body of the ilium, cranial to the acetabulum. A second hole was then drilled, cranial to caudal, through the base of the greater trochanter. Following reduction, heavy non-absorbable suture material was threaded through the holes and the suture material tightened. The suture material should not be tightened to the extent that flexion and extension of the hip is restricted, or the suture material will break. This technique achieves the same effect as transposition of the greater trochanter caudodistally, namely, internal rotation of the femoral head with slight abduction of the femur, which results in maximal coaptation of the acetabulum and femoral head.

h) Mehl (1988) described the technique of **pre-articular stabilization**, after a craniolateral approach to the joint followed by capsulorrhaphy. The principle is to avoid reluxation by limiting the range of rotatory movement of the femoral head, by the use of heavy double mattress sutures tied between the tendons of insertion of the psoas minor and the gluteus medius muscles. The mattress sutures placed between the two tendons lie just craniolateral to the joint, thus pulling the femoral head into the acetabulum while rotating the joint inward.

i) Although most caudoventral luxations can be handled by closed reduction, nevertheless some cases may require open reduction.

(i) Harari and others (1984) reported the treatment of 2 dogs with caudoventral hip luxation and concurrent fracture of the greater trochanter growth plate. Typically, a craniodorsal (Gorman's) approach to the hip was used, as it allows access to the acetabulum as well as to the trochanter. The joint was debrided, the luxation was reduced, capsulorrhaphy was performed, and the greater trochanter was re-attached to the femur by the use of a Steinmann pin and a tension band wire. No flexion sling type bandage was applied postoperatively.

(ii) Herron (1986) suggested that some cases of caudoventral luxation, not associated with trauma, are probably due to a deficiency in the transacetabular ligament, thus allowing ventral luxation. Following a ventral approach, four dogs had autogenous bone grafts, from the iliac crest, implanted on the ventral acetabular rim.

(iii) Wadsworth and Lesser (1986) (cited by Brinker and others, 1990) used the pectineus muscle to stabilise the femoral head. The muscle was detached distally and directed caudally ventral to the femoral neck, then dorsally and cranially over the femoral neck and deep to the gluteal muscles. The remaining free portion of the muscle was then sutured to any soft tissue available to hold the pectineus in position. Herron (1986) claimed the use of a soft tissue ventral sling implanted in three dogs.

1.6.3.7 Femoral head and neck excision

Hip luxations may ultimately require excision arthroplasty, which has been described by a number of authors (Ormrod, 1961; Spreull, 1961; Rex, 1963; Piermattei, 1965[a]; Hofmeyr, 1966; De Angelis and Hohn, 1968; Duff, 1975; Duff and Campbell, 1977; Gendreau and Cawley, 1977). However, femoral head and neck excision must be considered a salvage procedure, and reduction of the luxation should be attempted before resorting to this (Pettit, 1971).

De Angelis and Hohn (1968) stressed that satisfactory results have been obtained by femoral head and neck excision, as a salvage procedure, reserved for painful conditions of the hip which do not respond to less radical forms of treatment, such as many cases of severe hip dysplasia, miniature breed dogs with Legg-Calvé-Perthes disease, selected chronic coxofemoral luxations, certain fractures of the femoral head and neck, and osteoarthritis of the hip joint. Bone and others (1984) advocated that, if reduction cannot be maintained, femoral head ostectomy or a total hip replacement is preferable to a persistent luxation and subsequent pseudoarthrosis, as improved long term results are likely. Brinker and others (1990) considered excision arthroplasty a valuable method for improving the quality of life by relieving pain, through the elimination of bony contact between the femur and the pelvis, even though some gait abnormality persisted due to a slight limb shortening and some loss of range of motion. Bennett (1975) advocated the use of excision arthroplasty for all cats which suffered femoral neck fracture showing marked displacement of the femoral shaft, and in those cases of epiphyseal separation which show no substantial improvement after 2-3 weeks of conservative treatment.

Ormrod (1961) preferred the dorsal approach, in the heavily built animal, because, although this method involves much more interference with the muscles, it gives a more open access to the joint; in the case of lean and athletic type dogs the author followed the craniolateral approach. De Angelis and Hohn (1968) favoured the ventral approach because it maintains the integrity of the gluteal muscle group and the dorsal aspect of the joint capsule, and the sciatic nerve is not in the operative field and is not subject to injury. Piermattei (1965[b]) advocated that the craniolateral approach should be used on all breeds when there is a craniodorsal luxation of the hip - it provides adequate exposure and does not traumatise the gluteal muscles. The dorsal approach is used in large breeds when the head of the femur is in place.

Pettit (1971) stressed the importance of two principles which must be considered when performing this procedure: (i) all of the femoral neck should be removed so that no spur remains to perpetuate bone to bone contact; (ii) transection of the femoral neck should be made from ventral to dorsal, to avoid inadvertent amputation of the greater trochanter.

Brinker and others (1990) stated that leaving too long a neck that rubs on the dorsal acetabular rim is the most common reason for failure to achieve good function. Early active use of the limb is necessary. Passive range of motion exercises should be started immediately. Leash walking and freedom for the animal to move about a confined area should be encouraged until suture removal. In the difficult cases, swimming is perhaps the best form of physiotherapy.

1.6.3.8 Triple pelvic osteotomy (TPO)

Slocum and Devine (1986) described the use of this technique in 109 dogs: 105 dogs were diagnosed as having hip dysplasia, and 14 dogs as having dislocations from trauma or premature closure of the proximal femoral physis.

Pelvic osteotomy relies on reorientation of the acetabulum to improve congruency and stability of the femoral head within the acetabulum. By rotating the acetabular segment, the femoral head becomes firmly seated under the dorsal acetabular rim. This stability appears to decrease or halt the progression of osteoarthritis. The procedure is preventive in character and should be performed prior to degenerative joint disease for optimal results. Brinker and others (1990) stated that TPO is an effective method of treating hip dysplasia, especially in young animals. The operation should be done early, between 4 and 8 months of age, in order to take advantage of the remodeling capacity of immature bone. With instability and subluxation over a period of time, the acetabulum becomes filled with osteophytes and new bone that covers the original surface, thus preventing congruency between the femoral head and acetabulum. These changes become increasingly severe by the age of 10 to 12 months.

Slocum and Devine (1986) stated that age is not the most important criterion which determines the success of this procedure. The primary consideration is the condition of the joint surfaces. If the acetabulum is filled with bone, or the dorsal acetabular rim is lost due to eburnation, or the cartilage of the femoral head is destroyed, this will eliminate the possibility of congruency and the use of this procedure.

Each dog's hip is corrected individually, the amount of rotation of the pelvis being predetermined by eliciting the Ortolani sign under general anaesthesia. The femur is grasped distally, pressure is applied proximally and, as the femur is abducted, a distinct "click" is heard when the femoral head reduces. This *angle of reduction* is the maximum angle the acetabulum needs to be rotated to achieve stability. Reversing the procedure, by adducting the femur, results in another "click" when the femoral head subluxates from the acetabulum. This *angle of luxation* represents the minimal angle of rotation of the acetabulum that will produce stability of the hip. These two angles are used to select the appropriate implant for axial rotation of the acetabular segment of the pelvis. In order to prevent overrotation of the pelvis and subsequent impingement of the dorsal acetabular rim on the femoral neck, the angle selected should usually be closer to the angle of luxation than to the angle of reduction (Brinker and others, 1990).

Slocum and Devine (1986) devised a technique consisting of three distinct surgical procedures. First, a section of the pubic ramus was removed via a ventral approach and detachment of the pectineus muscle at its origin. The second surgical procedure consisted of the osteotomy of the tuber ischii via a caudal approach to the ischium, which allowed elevation of the internal obturator muscle and subsequent osteotomy of the ischial table from the lateral border of the obturator foramen caudally on a line parallel to the midline. Drill holes were then placed 5 mm from the cut edges, and a 1 mm wire was threaded through the holes but not tightened at this time. The third surgical procedure was the osteotomy of the iliac shaft. A horizontal reference line was created by passing a small blunted Steinmann pin from the dorsal surface of the tuber ischii cranially to a point one third the distance from the cranial ventral to the cranial dorsal iliac spines. The transverse osteotomy was 90° to the horizontal line and at the caudal aspect of the sacroiliac joint, protecting the cranial gluteal nerve at all times during this procedure. A 3.5 mm dynamic compression plate was then twisted to the predetermined angle of axial rotation of the acetabular segment, and placed perpendicular to the ilial osteotomy. The plate was fixed to the acetabular segment, and the bone spike, dorsally to the plate on the acetabular fragment, was removed. Returning to the ischial incision, the wire was tightened and the ends cut short. Finally, the ilial osteotomy was reduced, and the plate was applied to the ventral third of the cranial ilial fragment. No capsulorrhaphy was performed.

1.6.3.9 Total hip replacement

Total hip replacement (THR) consists of implanting a high density polyethylene acetabular cup and stainless steel femoral head component, after removing the femoral head and neck and preparing the acetabulum by reaming. These prostheses are permanently bonded to bone by polymethyl-methacrylate bone cement. At present, two sizes of prostheses are available, allowing replacement in most dogs over 18 kg. The procedure should not be done before the physes are closed. Thus, most large breeds cannot be operated before 12 to 14 months of age, but there are no specific upper age limits (Brinker and others, 1990).

Brown (1953[b]) described the use, in 3 dogs and 1 cat, of stainless steel lathed femoral head and shaft prostheses. No bone cement was used then, and the head was inserted directly into the acetabulum.

Brinker and others (1990) advocated its use, in addition to hip dysplasia, to replace hip joints damaged by degenerative joint disease from causes other than hip dysplasia, non-union or malunion of femoral head, neck or acetabular fractures, traumatic hip luxation, or avascular necrosis of the femoral head. This procedure is contraindicated in the presence of any infectious process, such as dermatitis, otitis, anal sac disease, dental disease, cystitis, or prostatitis, to prevent contamination of the surgical site, and neurological causes of abnormal gait, such as degenerative myelopathy, must be carefully eliminated as a cause of the dog's problems.

Eaton-Wells and Whittick (1990) stated that, although total hip replacement is only applicable to large breeds of dogs (over 25 kg), it has made some inroads and may be the method of choice in the near future.

1.6.4. Postoperative Management

Most authors consider that applying some form of flexion bandage to the limb following closed hip reduction is beneficial in preventing early reluxation.

On verifying reduction of a craniodorsal luxation, if there is evidence of free play or insecure retention of the head, Schroeder (1933, 1936) recommended placing the limb in a Thomas splint, applying sufficient long-axis traction to offset the displacing action of the gluteal and external rotator muscles due to spasm. In some cases it is necessary to also fix the limb in a position of moderate inward rotation, flexion, and slight abduction, to prevent a recurrence of the displacement, by tying up the splint alongside the animal's thorax. The animal must be kept confined, and the apparatus left for approximately ten days. In recent cases (up to two days) reduction is comparatively easy, and further treatment than a few days of confinement is rarely necessary.

Dibbell (1934) proposed the use of a straight cast, but making sure that the circular tension of the bandage counteracts the tendency of outward rotation (in cranial dislocations), or of inward rotation (in caudal dislocations). In a few cases, where simple extension does not hold the hip in place, Dibbell suggested that both hind limbs should be placed in splints and the "spreader" be applied, holding the limbs markedly abducted forcing the head of the femur into the acetabulum. Fixation is applied during six to ten days.

Ehmer (1934) advocated the use of a sling cast, for five days, bandaged from the hock over the body and back to the hock, then inside the thigh, over the body and back to the hock, placing each succeeding wrap a little further forward until the entire tibia is covered. In such cases where this type of cast did not suffice, Ehmer suggested the use of a "spread-cast", for five days, in the case of very unstable reductions, taking care that there is no strangulation of vessels due to cast pressure.

Shuttleworth (1950) advocated strapping the injured limb to the trunk until recovery from the anaesthetic is complete, in order to prevent redislocation during the incoordinate movement associated with recovery.

Bruere (1961) proposed the use of a strong plaster of paris cast, post surgical reduction, pressing tightly on the coxofemoral joint, in order to prevent redislocation during recovery from the anaesthetic. With this cast, which stays in place for six days, the dog is able to place weight on the limb, whereas figure-of-eight bandages are uncomfortable and to be avoided.

Pettit (1971) stated that manipulation of an articulated skeleton demonstrates that the femoral head is seated most securely in the acetabulum by flexion, abduction, and inward rotation. Effective bandaging techniques support the hip in one or more of these positions. Paradoxically, the more effective the restraint, the less comfortable it seems to be for the patient.

Herron (1979) advocated that the care of a coxofemoral luxation in the immediate post-reduction time includes checking that the femoral head is in a truly reduced position, and a reaming type procedure in which the femoral head is used to force out any haemorrhage and fibrin that may be present in the acetabulum. This trauma alone may be adequate to recreate the cohesive effect of the synovial fluid that helps maintain the joint in place. The author indicated that he preferred checking the reduced luxation at approximately 48 hours post-reduction because most hips that reluxate do so within a short time following reduction and sling application.

Alexander (1982) advised that, after closed reduction, the joint should be tested for stability to ascertain the most appropriate measure(s). If the femoral head snaps into place and is not readily dislocated, an Ehmer sling or figure-of 8 bandage should be applied for five days; if the hip is easily reduced but does not snap into place and tends to luxate, additional supportive measures should be taken, such as the De Vita pin. Although in some cases this pin allows immediate weight bearing, it is advisable to place the limb in an Ehmer-type sling for five days.

Campbell and others (1965) advocated the application of a figure of eight bandage, for three days, to maintain all the limb joints in full flexion and to adduct the stifle. Herron (1979) described the use of a sling, for a week to ten days following reduction, applied so as to rotate the stifle towards the midline, thus rotating the femoral head caudally into a neutral angle of anteversion.

Dallman and Mann (1981) reported on the use of a modified flexion sling. After reduction, the affected rear limb was flexed and maintained in flexion with non-elastic tape wrapped from medial to lateral. In addition, the flexed limb was placed in abduction with non-elastic tape that extended ventrolaterally and then dorsally over the back and around the body. The abduction thus obtained had the effect of driving the femoral head ventrally into the acetabulum, counteracting the tendency to reluxate dorsally. A further modification in the male required that the abduction band of the flexion sling be brought over and around the thorax to avoid incorporating the prepuce under the tape. In caudoventral luxations, the flexed limb was wrapped from lateral to medial. The flexed limb was then adducted and held in position with non-elastic tape that extended ventromedially and around the body. In every case the modified flexion sling was removed after 10 days, followed by two more weeks of exercise restriction.

Most authors nowadays suggest the use of an Ehmer-type figure-of-8 sling to immobilise the limb for 5 to 21 days - usually for 7 to 10 days (Fry, 1974; Gendreau and Rouse, 1975; Herron, 1979; Hammer, 1980; Dallman and Mann, 1981; Alexander, 1982; Duff and Bennett, 1982; Basher and others, 1986; Brinker and others, 1990; Tomlinson, 1990; Piermattei, 1993), to achieve limited motion, which is necessary for an optimal increase in the tensile strength of the joint capsule during the healing process. Fox (1991) stated that, because of the natural canine resistance to hyper flexion, there is considerable pressure at the edges of the bandage, which may cut at the underlying soft tissue. Resistance to hyper flexion by the encircling tape produces pressure on the plantar aspect of the metatarsus; such pressure may lead to oedema and swelling. Sufficient padding thus must be applied around the metatarsal area before application of the figure of 8 sling, and the foot should be examined daily for swelling.

After removal of the bandage, Hammer (1980) suggested an exercise program consisting of: **(i)** Limited walk once a day, on a leash, during the first 3 weeks; **(ii)** Walk, as long as the patient will tolerate, but only on a leash, for the next 3 weeks; **(iii)** Unrestrained activity after the sixth week.

Fry (1974), Bennett (1975) and Duff and Bennett (1982) stressed that <u>cats</u> do not tolerate such figure-of-eight flexion bandages as well as dogs. However, cats are recognised as being better orthopaedic patients than dogs, and are more adept at resting an injured limb.

Fry (1974) did not use any kind of bandaging postoperatively, but exercise was not permitted during the first 4 days and then the patient was only allowed short walks on a lead for 3 weeks, gradually returning to normal exercise over a further 2 week period. Mehl (1988) did not apply any form of bandage postoperatively to the pre-articular stabilization technique (used in 4 cats and 7 dogs), but he advocated restricted exercise for three weeks.

Knowles and others (1953) and Lawson (1965) did not use any kind of postoperative fixation after the use of the toggle pin technique, and normal walking exercise was permitted immediately. Brinker and others (1990) and Denny (1993) advocated that after toggle-pinning the leg should be strapped in flexion for 5 days, and strict exercise restriction should be imposed for 4 weeks postoperatively. Denny and Minter (1973) proposed only cage confinement for 5 days and restricted exercise for 1 month. Lubbe and Verstraete (1990) proposed that no external support or sling bandage should be used postoperatively to the fascia lata loop stabilisation technique. The patients were confined to a cage for a week and exercise restriction was imposed for a further six weeks.

Horne (1971) proposed cage rest or limited exercise in a run area for 7 to 10 days, by which time the trochanteric pin was removed. Gendreau and Rouse (1975) proposed that postoperatively, the leg should be placed in an Ehmer sling until the transarticular pin was removed (10 days in animals having relatively normal hip joints, and 21 days in animals with dysplastic hips), but Bennett and Duff (1980) did not use any type of flexion bandage and the transarticular pins were only removed 1 month after surgery. Wallace (1983) and Hunt and Henry (1985) advocated the application of an Ehmer sling postoperatively. The transarticular pin and the Ehmer sling were removed in 10 to 14 days (3 weeks in the case of dysplastic hips) and the animal's activity was restricted for a further 3 weeks after pin removal.

Leighton (1985) advocated that, after open reduction with the dorsal capsular prosthesis technique, the dog should be confined for about 10 days, but should be allowed to use the leg. Allen and Chambers (1986) proposed that a non-weight bearing sling can be placed to protect the reduction, if the opposite limb can bear full weight, but is not mandatory. Johnson and Braden (1987) advocated that, in most cases, an Ehmer-type sling should be placed on the operated limb for 7 to 10 days postoperatively, and exercise restriction is recommended for 4 to 6 weeks.

Duff and Bennett (1982) advocated that, in cases of recurrent or chronic hip luxation, the relocated joint requires some form of support for at least eight weeks, particularly when De Vita pinning, hip toggling, or transarticular pinning had been used, strict rest being of utmost importance during the postoperative period.

Slocum and Devine (1986) reported that, after triple pelvic osteotomy, the dogs were confined to the house for four weeks.

Thacher and Schrader (1985) reported that postoperative reduction of 14 **caudoventral luxations** was maintained without internal or external fixation in all but one case, which had an adduction sling. Tape hobbles were used in three dogs. Owners were advised to limit the activity of the dog for four weeks and to keep the dog in an area that provides good traction, rather than slippery floors.

No matter what manner of care and fixation is used, a post-reduction radiograph should be made to confirm the position of the femoral head (Alexander, 1982).

1.7. Prognosis

It is obvious from the volume of work it has encouraged that dislocation of the hip, in many instances, can present difficulties in the matter of reduction and maintenance (Campbell and others, 1965).

The many techniques that have been advocated for the treatment of coxofemoral luxation reflect the lack of consistently good results by any one of them (Stead, 1970).

Shuttleworth (1950) suggested that even though the joint will function quite well, arthritis of the hip might develop, following a successful reduction of coxofemoral luxation. Stead (1970) recorded only two cases (10.5%) of arthritis in a series of nineteen successfully reduced hips which is, perhaps, surprising in view of the degree of tissue damage which must occur in the majority of cases; it would appear, therefore, that the canine hip joint has a remarkable capacity for restabilization and recovery from severe trauma to its tissues following a successful reduced luxation. Bone and others (1984) reported on the long-term radiographic changes, 14 to 40 months following successfully reduced hips on 10 dogs (11 dislocated hips). Three of the ten dogs exhibited no lameness or DJD, and three had both lameness and DJD; three dogs had radiographic evidence of DJD without lameness, and one dog had a grade I lameness without DJD; none of the ten dogs had worse than a grade I lameness. The radiographic changes did not therefore correlate well with the clinical signs. The authors considered that the reason for the higher incidence of degenerative joint disease (as compared to the report by Stead, 1970) following successful reduction might have been the length of the follow-up period.

Piermattei (1982) stated that the prognosis varies with the stability achieved following reduction, and with the time interval between luxation and reduction. Those cases that are reduced early and which reduce with good stability carry a good prognosis and normal function may be anticipated. Those cases that have been luxated for a considerable length of time, and most especially in immature animals, may result in avascular necrosis of the femoral head. Occasionally a hip may reluxate after reduction, although this is rare if reduction is maintained for seven to eight days. Varying degrees of osteoarthritis may develop if there has been sufficient damage to the acetabulum or femoral head.

Basher and others (1986) stated that no difference in the long term result was found between the closed and open reduction groups and that, in most cases, a good prognosis could be given for the return of limb function, depending on the severity of other injuries, when successful closed and open reductions were maintained postoperatively. The detection of hip dysplasia or DJD at the time of presentation suggests a guarded prognosis for the success of reduction, 64% of these patients having been eventually treated by excision arthroplasty.

Perez-Aparicio and Fjeld (1993), in a retrospective study of 79 untreated coxofemoral luxations in cats, stated that cats are able to disguise their handicaps, which placed certain limits on objective evaluation of physical discomfort and function by the owners and also by the clinician. Almost two-thirds of the re-examined animals presented some kind of locomotor dysfunction (not necessarily pain associated with lameness) on clinical examination. The best clinical results were observed in cats that were immature at the time of injury, which could be due to a young animal's greater potential for bone remodelling and the development of a functional nearthrosis similar to a normal coxofemoral joint. As cats are not subject to major physical demands, the clinical performance at follow-up was acceptable and the animals had a normal level of activity according to the owners.

1.7.1. Closed reduction

A proportion of closed manipulative reductions reluxate, either almost immediately, or at a variable time afterwards.

(i) Green and others (1953) revealed the results of a survey which showed that 14.7% (235/1588) of coxofemoral luxations recurred after closed reduction and immobilisation of the limb with a figure-of-8 Ehmer splint, with or without the use of sclerosing agents.

(ii) Bruere (1961) reported pseudoarthrosis formation as satisfactory functionally in most cases, except on exercise. Dobbelaar (1963) stated that in a series of 11 documented failures, five were destroyed due to persistent lameness, one recovered completely and five were able to walk short distances without lameness. Campbell and others (1965) in their survey mentioned 3 cases in which reduction was unsuccessful; of these, two remained marked persistently lame as long as two years after the accident and the third became sound after three months. Stead (1970) reported that reluxation had occurred in 44% (15/34) of the dogs he re-examined with consequent pseudoarthrosis formation; while a pseudoarthrosis is not the most desirable end result, the evidence from this series is that its function, in the majority of cases, was remarkably good. Bone and others (1984) advocated that, if reduction cannot be maintained, femoral head and neck excision or a total hip replacement are preferable to a persistent luxation and subsequent pseudoarthrosis, as improved long term results are likely.

Schroeder (1936) stated that the prognosis in all dislocations of the hip is dependent upon the reduction and its maintenance. In those cases where a reduction has been obtained and where there is no indication of recurrence to reversed manipulation, complete recovery may be expected in at least 90% of the cases, as long as reduction is maintained by fixation for 2 to 3 weeks.

Campbell and others (1965) claimed 89% success rate (107/120) in a survey involving 120 cases of hip dislocation which were treated by manipulative reduction. In the majority of cases (102) reduction was accomplished and maintained at the first attempt (85%). Fry (1974) reported 64.8% success rate in a series of fifty-four cases which underwent closed reduction. Bennett (1975) reported 88.9% success rate (16 of 18) in cats which were treated by external reduction, with most cases being sound by the second and third weeks and showing good joint mobility with no pain. Herron (1979) reported that no known cases of normal hips that had been reduced by closed manipulation and maintained in a sling for a week to 10 days had follow-up problems with the hip, but no figures were given. Dallman and Mann (1981) claimed that all patients (5 dogs and 1 cat), which were treated by closed manipulative reduction followed by the application of a modified flexion sling, for approximately ten days, were using their limbs 3 to 4 weeks after the initial closed reduction.

McLaughlin and Tillson (1994) considered that some of the potential complications associated with the use of Ehmer slings include injury to the skin or deeper tissues, premature removal of the sling, and recurrent luxation.

Campbell and others (1965) advocated prompt treatment advisable as this was borne out by the fact that in only 3 out of 91 dogs in which treatment was carried out in less than seven days was the outcome of closed reduction unsuccessful, a success rate of 96.6%. Of the animals in which the injury was known to have occurred seven days previously or more reduction and stabilisation by conservative means had a success rate of 69.6% (16/23). When reduction was achieved and maintained, however, knowledge of the length of time which had elapsed prior to treatment was of limited value in forecasting the return to soundness. Duff and Bennett (1982) considered that closed hip reduction is less likely to succeed if the luxation occurred more than ten days previously (80% of the successful closed reductions were performed within ten days of luxation). Nevertheless, closed hip reduction was successful in two dogs five weeks, and one cat twelve weeks after luxation, which supports the suggestion that closed reduction is a worthwhile initial form of treatment in all cases. In their survey involving luxations in 127 dogs and 13 cats, closed manipulative hip reduction achieved a 65% success rate in dogs (83/127) and 69% in cats (9/13).

Bone and others (1984), reporting on the results of a survey, indicated that reluxation occurred in 47.3% (35/74) of the closed reductions and in 60% (3 of 5) of the hips where an external skeletal fixator was used. The authors recommended closed reduction as the initial treatment (even though the risk of recurrence is higher than surgical reduction), as the need for surgery may be avoided in approximately one half of affected dogs, since there was no significant difference between the recurrence rates of surgical reduction as the initial procedure compared to surgical reduction following failure of closed reduction.

Basher and others (1986) reported a failure rate of 64.8% (46 of 71 dogs and cats) for closed reduction, which may in part reflect the skill level of the clinician because the majority of these patients had a first attempted reduction at the referring hospital and the remainder were treated initially by an intern.

Nunamaker (1985) stated that the causes of failure of closed reduction are usually associated with fracture fragments of the femoral head or acetabulum, or soft tissue positioned between the femoral head and acetabulum. Other reasons for failure of closed manipulation are related to abnormal hip development (hip dysplasia) and osteoarthritis.

Leeds and Renegar (1979) reported encouraging results with the use of the **De Vita pin** in 5 multi-traumatised dogs. Read (1980) reported on one dog with bilateral hip luxation who was walking well within ten days of surgery. Duff and Bennett (1982) reported 64% success rate out of a series of 41 dogs which were treated with the De Vita pinning technique; this technique was successful in maintaining the hip reduced in 3/6 dogs which presented hip dysplasia. The commonest causes of pinning failure were related to failure to locate the pin securely through the wing of the ilium, failure to insert the pin beneath the ischial tuberosity, and cranial migration of the pin (suturing the pin was not always successful in preventing migration, but a possible solution would be to use threaded Steinman pins rather than the trocar pointed pins routinely used in this survey). Migration occurred as early as five days postoperatively, and discomfort and pain were the signs associated with it. Despite these problems, De Vita pinning was successful even when five weeks had elapsed since the luxation.

McLaughlin and Tillson (1994) reporting on the experimental results with an **external fixator connected by a flexible band**, stated that the dogs tolerated the fixator well and were bearing weight on the limb within 2 days after surgery, and walking with only minimal lameness 5 days after surgery (the range of motion was not limited by the fixator). Furthermore, reluxation did not occur during the 2 week period in which the fixators were in place, and the joints remained stable 1 week after removal of the fixators, by the time the dogs were euthanised. Some of the complications encountered included superficial infections, drainage from the pin tracts and enlargement of the stab incisions, which all began to heal quickly after removal of the pins. Potential complications, not observed in this study, are injury to vessels or nerves in the region (cranial gluteal artery and vein, and cranial gluteal and sciatic nerves), premature loosening of the pins, spread of infection into deeper tissues, recurrent luxation of the joint, and damage to the articular cartilage by tightening excessively the band, thus interfering with joint motion. The authors considered the flexible external fixator to have several advantages over existing methods of treating coxofemoral luxations: It maintains the femur in a similar position as the Ehmer sling, yet it allows weight bearing and joint motion and it avoids the difficulties encountered in maintaining the sling or bandage; it can be applied in cases where concurrent orthopaedic problems contra-indicate the use of a sling on the luxated side; the fixator is inexpensive and is easily and quickly applied in a closed fashion, the implants are readily removed and no foreign materials remain in the patient; the fixator does not damage the articular surface and permits weight bearing and joint motion soon after surgery.

Thacher and Schrader (1985) claimed that, with the exception of two dogs (14.3%) with chronic instability, all of the **caudoventral luxations** were successfully reduced by the closed method, which meant 85.7% (12/14) success rate. In 3 cases, successful reduction was achieved 7 to 12 days following the initial trauma. The successful outcome of treating caudoventral luxations is related directly to the intact dorsal supporting structures of the hip joint (the gluteal muscles, the dorsal joint capsule, and the acetabular rim). After the hip is reduced, these intact structures support the weight of the dog and maintain the stability of the hip during normal ambulation. For the femoral head to reluxate caudoventrally, the limb must be adducted again, which can be prevented by the use of tape hobbles, which, however, have the disadvantage of increasing the dog's chances of falling.

1.7.2. Open reduction

The variety of techniques and materials used in surgical repair of coxofemoral luxations suggests that no single ideal method exists (Alexander, 1982; Duff and Bennett, 1982).

Recurrent luxation, implant migration or failure, neurological damage, infection, injury to the articular cartilage or periarticular tissues, and the expense of surgery are all potential problems associated with surgical treatment of coxofemoral luxations. Nevertheless, surgical techniques provide better stability and significantly decrease the risk of luxation, when compared to a much higher recurrence rate of closed reduction (Bone and others, 1984). The authors reported that capsulorrhaphy, trochanteric transposition and transarticular pinning resulted in luxation recurrence in 9.5% (2/21), 12.5% (1/8), and 14.3% (1/7), respectively. One of four luxations repaired by the toggle pin technique recurred.

Brown (1953[a]) reported a limited use of the legs seven days postoperatively and complete return of function and absence of pain at three weeks, after using the dorsal approach to the joint by tenotomy of the gluteal muscles. Piermattei (1993) stated that function is not regained as quickly with this approach as with the osteotomy of the greater trochanter, but considered this approach preferable to osteotomy in the skeletally immature animal, because there is no disruption of the physis of the greater trochanter.

Bruere (1961) reporting on the results of the reduction of coxofemoral luxation on thirty dogs, stated that the more recent the dislocation the better the result of the operation, though in several cases dislocations as old-standing as four or five weeks had responded satisfactorily to open reduction. Hammer (1980) stated that there appeared to be no relationship between the length of time the leg had been luxated before surgery and successful surgical reduction.

Garbutt (1948) claimed that his two cases were walking normally within two weeks after removal of the **transarticular screw**.

Helper and Schiller (1963) claimed good results in all 9 dogs and one cat, which were subjected to their **acetabular rim plastic prosthesis**, except for one dog which showed limping, pain, and an occasional refusal to use the limb. Dobbelaar (1963) reported a 77% success rate in thirty cases which were treated surgically using two **bone grafts which increased the acetabular rim**, thereby preventing redislocation, although difficulties were found in acute luxations, with marked contusion about the joint, and in long-standing dislocations where reduction became most difficult. Horne (1971) recommended that his **trochanteric pinning** procedure was primarily indicated for dogs weighing less than 20 kg (the pin may break in heavy dogs), however, he had achieved consistently encouraging results in 15 patients. Fuller (1972) claimed that normally the dog walks on the operated leg within one to two weeks after the use of the **threaded pin** technique, but the author did not indicate any figures on the number of animals operated. Marvich (1972) reported 92.7% (12/13) success rate of his technique consisting of the insertion of a **cortical screw to extend the acetabular rim**. Radiographs taken six to nine months postoperatively gave no evidence of degenerative joint disease.

Hansmeyer (1963) claimed 100% success rate in 34 dogs treated with the **purse string suture** technique, with the dogs using the leg 48 hours postoperatively. MacDonald (1964) reported having used this technique in 4 dogs: three progressed very well, but in one dislocation recurred within six days due to failure of the suture material; the dog was re-operated and the second try was successful. Both authors stressed the fact that this procedure is indicated only in cases of coxofemoral luxations which are easily reducible, but which recur upon manipulation, and it should not be employed when other pathology is present such as hip dysplasia, acetabular fractures, or fractures of the femoral head or neck.

De Angelis and Prata (1973) achieved 83.8% success rate with **trochanteric transposition**, with 31 out of 37 dogs which were found to be normal or nearly so 24 months postoperatively - 6 (16.2%) had a slight occasional lameness, usually after exercise, and 25 (67.6%) were completely asymptomatic. The six unsuccessful cases (16.2%) reluxated within 4 months, and excision arthroplasty was performed. When pre-operative radiographs of these unsuccessful cases were re-evaluated, bony abnormalities were found in 4 cases. Hammer (1980) reported 75% success rate on 15 dogs and 1 cat, with recurrent luxation, which were treated by open reduction, capsular repair and trochanteric transposition. Basher and others (1986) claimed 100% success rate among 5 cases which were treated with trochanteric transposition.

Fry (1974) reported 86% success rate of open reduction by **gluteal myotomy** without capsular repair, or trochanteric transposition, in a series of 15 dogs and 3 cats. The follow-up period involved 14 operations from 6 months to 3.5 years. In 12 cases the animals showed no weakness, lameness or pain. One patient, which had previously experienced a fractured pelvis, later developed femoral head necrosis and an excision arthroplasty was performed, and another animal redislocated the hip seven days post-surgery and was subsequently re-operated.

Gendreau and Rouse (1975) reported 74% success rate with the use of the **transarticular pin** in a long term evaluation (on an average of 28.1 months after surgery) of 27 dogs. 20 dogs had normal use of their operated leg at the time of the survey, and 7 cases had complications. In 2 of the cases, severe hip dysplasia led to reluxation in one case and crippling arthritis in the other case; in 2 other cases, acetabular fractures, on the same side as the dislocation, were believed to have contributed to the arthritic changes that eventually required excision arthroplasty of the femoral head and neck; in another case, with bilateral coxofemoral dislocations and a luxation of the tarsal joint, there was reluxation of the hip on the same limb that required repair of the tarsal luxation; in another case, a delayed union of a fracture of the contralateral femur lead to reluxation of the hip two weeks after pin removal; in an additional case, a cat re-examined three months after hip pinning was found to have a chronic dislocation. The authors recommended this technique for the treatment of complicated coxofemoral luxations, and they considered it to be a reasonable and highly successful alternative to femoral head and neck excision in the absence of severe hip dysplasia as a complicating factor.

Bennett and Duff (1980) claimed 100% success rate with the use of the transarticular pin technique (6 dogs and 1 cat). The authors stated that 1 month after surgery all the animals were using the limbs well, except for one case (which eventually became sound) with concurrent fractures of the right femur and left tibia. In all cases the animals were able to flex and extend the hip joint, the femur pivoting on the transarticular pin. Radiography showed that the pins had not displaced from their original positions and no secondary arthritic problems were apparent. The pins were then removed and this allowed for non-painful abduction of the hip joints.

Hunt and Henry (1985), reporting on the long-term results (mean follow-up period of 18.4 months) of transarticular pinning used for the repair of hip dislocations in 40 dogs, stated that satisfactory (good to excellent) results were achieved in 80% of the cases (32/40). The remaining 8 dogs were judged fair (5%) or poor (15%) and were classified as unsatisfactory. Body weight had a significant influence on outcome. All dogs weighing less than 20 kg had satisfactory outcomes; of the 20 dogs weighing more than 20 kg, 8 (40%) had unsatisfactory results. No significant difference was found between the median pre-operative interval for dogs with a satisfactory result (3 days) and those with an unsatisfactory result (4.5 days). Previous attempts at closed reduction followed by stabilisation with a hip bandage or a De Vita pin did not seem to affect the outcome of transarticular pinning in this series. The results in this series did suggest that the presence of ipsilateral hip fractures, both in the femoral head or the acetabulum, may adversely affect long-term prognosis due to an increased tendency toward the development of degenerative joint disease. Hip dysplasia, with or without pre-existing DJD, was an important factor influencing results, with all 3 dogs with dysplastic hips having developed severe osteoarthritis in the injured hip, thus the authors' suggestion that in such cases excision arthroplasty or total hip replacement should be considered. The most frequent complication was pin breakage (11 cases), but it did not affect long-term results. Dislocation recurred in 3 cases, osteonecrosis of the femoral head and neck developed in 2 cases, wound infection developed in 1 case, and sciatic nerve injury developed in 1 case. Driving the pin through the articular cartilage did not appear to be associated with any problems, which is consistent with Mankin's findings (1981), who stated that if the cartilaginous injury extends to the subchondral bone or if defects are drilled so that the underlying bone is entered, one can anticipate exuberant formation of repair tissue, which in a very short period of time produces a mass of hyaline cartilage to replace the damaged cartilage surface or ulcer. Mankin (1981) also stated that the type of cartilage produced may not be "normal", and that this tissue may undergo localised degeneration over time, a circumstance that may be partly modified by the institution of a postoperative physiotherapy programme consisting of passive motion exercises, which would cause the defect to heal more rapidly, with tissue more closely approximating hyaline cartilage than fibrocartilage.

Wallace (1983) stated that the most common complication of the transacetabular pinning technique was the breakage of the pin at the area of greatest stress in the acetabulum, which could be avoided by using a non threaded pin that occupies 50 to 75% of the diameter of the fovea capitis and by keeping the limb in an Ehmer sling while the pin is in place.

Replacement of the ligament of the head of the femur with fascia or synthetic material (Knowles and others, 1953), was reported to be 100% successful. Knowles and others (1953) considered that the success of this technique, in the 6 cases reported, was due to the fact that it is relatively atraumatic, that it is physiological, and that it permits continued action of the hip joint. Zakiewicz (1967), who used skin, reported 75% success rate (3/4) in experimental dogs, one dog showing persistent lameness due to the fact that the point of attachment of the ligament to the acetabulum was 1 cm above the acetabular fossa. In the clinical group consisting of 5 dogs with recurrent hip luxations, from two to four weeks duration, recovery was slower than in the experimental dogs and lameness persisted for 4 to 8 weeks, and one dog developed a sinus tract leading to the wire, but this subsequently resolved after the wire was removed. The author decided on this type of prosthesis based on the results obtained by Vaughan (1963), who claimed that whole thickness skin proved to be superior to either fascia or nylon as a replacement material for the cranial cruciate ligament - three months postoperatively the skin grafts were intact and despite shrinkage were similar in calibre and strength to a normal cruciate ligament. Lawson (1965) stated that recovery of function of the limb was often virtually complete within a period of 3 days of operation, and that the factors which predisposed to poor results were related to those which have produced deformities of the femoral head with damage to its articular cartilage, such as long standing dislocations where the dog had been carrying weight on the leg.

Denny and Minter (1973) reported 78.6% success rate (11/14 cases), with most dogs using the leg at four weeks postoperatively. One animal died suddenly 2 weeks after surgery, one obese dog which had a bilateral dislocation made no attempt to stand and was destroyed, and in a third case the **hip toggle prosthesis** broke at one month postoperatively. Similarly, Duff and Bennett (1982) reported the breakage of the prosthetic ligament in 18.5% (5/27) of the dogs, operated with this technique, between four and eight weeks postoperatively. The accurate placement of the prosthetic ligament is essential since if it does not coincide with the pivot of the hip joint action, it will be predisposed to failure. Brinker and others (1990) stated that the synthetic teres ligament that is created is not expected to function indefinitely, but it will maintain stability until the soft tissue damage in the region of the hip joint has undergone healing with maturation of the scar tissue and reformation of the joint capsule. No evidence has ever been seen in which the suture material used to create the synthetic teres ligament has created a problem in the joint, and in those cases that have reluxated and been re-operated, the broken suture material has been encapsulated in the regenerating teres ligament and thus was no longer intrasynovial. Denny (1993) claimed that 84% of the cases operated will regain full limb function, the main complication being premature breakage of the prosthesis due to over activity during the recovery period, hip dysplasia, and muscle contraction in long-standing dislocations. Also, if dislocation occurs in an immature dog, before closure of the proximal femoral growth plate, then rupture of the joint capsule may lead to ischaemic necrosis of the femoral head, in which case excision arthroplasty should then be carried out.

Lubbe and Verstraete (1990) claimed 91.7% success rate in a series of 10 dogs and 2 cats which were operated with the fascia lata autograft as a prosthetic teres ligament. Only 1 dog reluxated the joint, three weeks postoperatively, supposedly because capsulorrhaphy had not been originally performed. The authors advocated the use of a fascia lata autograft combined with repair of the joint capsule for the reduction of long-standing hip dislocations or unsuccessful closed reductions.

Zaslow and Hanson (1975) reported 100% success rate, in one dog and one cat which were subjected to the technique of **fascia lata transplantation capsular repair**. According to the authors, this procedure can only be attempted if the hip joint shows no signs of dysplasia.

Mehl (1988) claimed good results in 4 cats and 7 dogs which were subjected to the **pre-articular stabilization** technique. The technique proved to be a simple and effective method of treating craniodorsal luxations in both cats and dogs. In all cases there has been a very short convalescence (the average postoperative lameness period was four days), and no reluxation except in one dog which reluxated, four months after the operation, due to trauma. Using the tendons to anchor the mattress sutures instead of the bone makes the stabilisation elastic which may explain the short convalescence.

Leighton (1985) claimed good results, in both large and small dogs which underwent open reduction and the **dorsal capsular prosthesis** technique. Reaction to the suture material seems limited to the development of a heavy mass of scar tissue that envelopes the sutures, thereby producing a thick joint capsule. Allen and Chambers (1986) considered the effects of the extracapsular suture stabilisation technique similar to those of an Ehmer sling in that external rotation and adduction are limited. However, in contrast to an Ehmer sling, early weight bearing can be allowed on the surgically reduced hip. Flexion and extension are not limited by the sutures, although internal rotation is limited somewhat by the caudal suture. Although there is some limitation of range of motion in the hip, it is temporary and considered necessary for maintenance of reduction during healing of the joint capsule. The authors claimed uneventful recoveries in 5 dogs which underwent this surgical procedure.

Johnson and Braden (1987) reviewed 21 hip luxation cases (all dogs), operated with the dorsal prosthetic technique, that were either recurrent or greater than 7 days duration (15 of 21 cases were operated 2 or more weeks post injury). Follow-up information, ranging from 4 to 40 months, was available for 17 dogs. The procedure provided good or excellent results in 11 of 17 dogs (64.7%). Complications from the surgical repair were few. In two dogs reported as having poor function, avascular necrosis of the femoral head was evident (it was present in one dog pre-operatively and in the other dog it was noted one month postoperatively) - both conditions could have been due to vascular embarrassment of trauma or delay in repair; one dog had a reluxation due to slippage of suture material off of the screw heads, which were initially placed without washers. Neither infection nor reaction to suture material was found to be a complication of prosthetic capsule surgery in the cases reported. The authors claimed that although their 64.7% success rate was not as high as some studies concerning other techniques, the majority of the cases in this study were recurrent or long-standing luxations and cannot, therefore, be compared.

It is apparent that no operative procedure is superior to any other procedure in preventing reluxation. Repair of the teres ligament and joint capsule or trochanteric transposition, appears not to influence the rate of success of reduction, since Fry's procedure, that uses neither technique, is as successful in preventing reluxation (Hammer, 1980).

Meij and others (1992) claimed good results with the **extra-articular stabilization** technique. At an average of three weeks postoperatively, 81% (13 of 16) of the patients were sound. The success rate proved to be strongly related to the suture material (2 out of 3 reluxations were due to suture breakage) and varied from excellent to poor. The technique had excellent results in acute and chronic coxofemoral luxations in dogs when multifilamentous non-absorbable material was used, even when no additional non-weight bearing sling was used. In 2 cases of bilateral luxation recovery was complicated by sciatic neuropathy, probably due to the extensive trauma to the pelvis and associated fractures in both cases.

Harari and others (1984) claimed good results in 2 dogs with **caudoventral hip luxation**, which were subjected to open reduction and **capsulorrhaphy**. Both cases began using the limb on the fourth postoperative day, and were walking normally at the time of suture removal. Herron (1986) reported that of the six dogs operated to reduce caudoventral luxation, three had a **soft tissue ventral sling** implanted, which was unsuccessful, and two of the dogs were subsequently resolved with **femoral head and neck excision**. The third case was secondarily operated with a **ventral acetabular homograft** from the iliac crest. The three additional dogs were operated with grafts. All six responded to the selected therapy, but the grafts appeared to be a more satisfactory method of resolving the problem.

According to Brinker and others (1990), the prognosis for **excision arthroplasty** depends on surgical skill, length of time the hip pathology had been present, and the severity of the pathology.

Spreull (1961) reported on 7 cases (all dogs), and claimed 5 successful outcomes, 1 partial success and 1 failure. Ormrod (1961) claimed 100% success rate in 5 dogs which underwent femoral head and neck excision. Rex (1963) reported 90.9% success rate in a series of 9 dogs and 2 cats. Piermattei (1965[a]) claimed that pain was consistently eliminated, in a series of 10 dogs, and this is perhaps the most important justification for the procedure. In 80% of the cases the dog was able to resume its normal activities and thus remained a suitable pet. Hofmeyr (1966) claimed that excision arthroplasty achieved its purpose in 83.3% of a series of 18 dogs, of both large and small breeds. De Angelis and Hohn (1968) reported that 65.5% (19/29) of a series of unilateral excision arthroplasty patients (cats and dogs) were able to walk in a normal manner, even though the operated limb was shorter. However, in 8 cases there was temporary lameness following exercise, or temporary stiffness upon first arising. In 4 cases, all large dogs, there was moderate to severe limping, often with marked loss of stability of the operated limbs, up to six months postoperatively.

Duff (1975) stated that excision arthroplasty is a worthwhile operative technique for the treatment of conditions of the canine hip. However, a number of postoperative features, such as limb shortening, muscle atrophy and limitation of joint mobility, should be considered to be common outcomes. Continuous lameness is not a common sequel to femoral head and neck excision and it seems that manifestations of lameness, or particular locomotory difficulties, result from strain of the fibrous and soft tissue elements of the pseudoarthrosis. Large bony spurs left at the resection site can give rise to a less satisfactory postoperative result, but small bony protuberances subsequently undergo remodelling and ultimately will disappear. Weight bearing changes resulted in growth deformities in the non-operated limbs of experimental sheep and the finding of patellar luxation in some dogs suggests that this could also be a feature in the canine patient.

Gendreau and Cawley (1977) reported on the results of 35 excision arthroplasties performed in 31 dogs and 4 cats. Excellent results were achieved in 37.1% of the cases (10 dogs and 3 cats); good results were reported in 25.7% of the cases (9 dogs); the operation produced fair results in 25.7% of the cases (8 dogs and 1 cat); 11.4% (4 dogs) were categorised as poor results. The findings of this survey suggest that: **(i)** The weight of the patient may have a bearing on the outcome of the operation - the average weight of the patients with excellent results was 8 kg as compared to 16.7 kg for animals with poor results; **(ii)** The age of the patient at the time of surgery did not appear to have any bearing on the outcome of the operation; **(iii)** The duration of the clinical signs may have been a factor in the outcome of surgery - animals with poor results had a history of lameness lasting more than 6 months, while those with excellent results had clinical signs averaging only 1 month in duration. Although it was not studied in this survey, it is the authors' belief that good surgical technique increases the chance of success, particularly in larger dogs.

Duff and Campbell (1977) analysed the long term results of femoral head and neck excision in 135 dogs. 62 of these dogs were re-examined. 93% of the owners indicated satisfaction with the results. Although a considerable proportion of the animals were reported to be lame, only 10% were found to be lame on re-examination, which indicates that excision arthroplasty may be recommended with confidence for the treatment of chronic hip lameness. Most of the animals showing lameness were of the larger breeds, indicating the greater stress likely to be applied to the pseudoarthrosis in such animals. Small breed dogs developed patellar subluxation (18% of the dogs re-examined), mostly of the non-operated limbs, although in no case was this clinically significant. Nevertheless, Brinker and others (1990) considered that although smaller breeds experience less change in gait, the operation is usually successful in large breeds for relieving pain and restoring the animals' quality of life.

Slocum and Devine (1986) stated that, after **triple pelvic osteotomy,** although capsulorrhaphy was not performed with this technique, after six weeks with the hips in a stable position the stretched joint capsule began to tighten, thereby maintaining the femoral head firmly seated under the dorsal acetabular rim. This stability appeared to decrease or halt the progression of osteoarthritis. The main complications were a limitation in the abduction of the femur, constipation which occurred three to five days postoperatively, loss of fixation and breakage of the plate which occurred in 10% of the cases, and urethral impingement which was observed in one dog which had bilateral pelvic osteotomies before this technique was modified to remove the segment of bone from the pubis.

2. Materials and Methods

2.1. Aims of the Project

Coxofemoral dislocation is the most common traumatic luxation in the dog and cat. Craniodorsal luxations account for 85% to 95% of all hip luxations.

Various methods have been described to effect reduction of the hip luxation and to maintain the hip in position, thus stabilizing the joint sufficiently, to allow soft tissue healing. Many dislocated hips require surgical treatment. Each of the many surgical procedures aims to prevent redislocation which occurs if the femoral head is allowed to clear the dorsal acetabular rim. Thus, every surgical technique attempts to prevent lateral movement of the proximal femur. Different surgical techniques presumably have different levels of resistance to lateral displacement of the femur, although this has not yet been determined.

The stability of the canine hip joint is governed by the congruency of the articular surfaces, the integrity of the joint capsule, teres ligament and cartilaginous labrum, combined with the overall strength and mass of the pelvic musculature (Riser, 1975). Surgical methods of coxofemoral stabilization have concentrated on achieving maximum perceived stability, sometimes at the cost of articular surface disruption. The relative stability of these methods of stabilization has not been assessed and it is unknown whether the more invasive techniques indeed offer superior stability. It is also unknown how closely any of these techniques compare with the stability of the normal dissected hip *in vitro*.

The aim of this project was to compare the lateral ("pull-out") resistance to reluxation in cadaver material between a control group and four methods of stabilization of coxofemoral dislocations: **(i)** Capsulorrhaphy; **(ii)** Transarticular pin; **(iii)** Dorsal capsular prosthesis; **(iv)** Toggle pin.

2.2. Hypothesis of the Project

The hypothesis of the project is that techniques that are very successful clinically, differ in resistance and some have considerably lower resistance than the normal intact supporting soft tissue structures of the joint.

2.3. Preparation of the Specimens

2.3.1. Selection

Twenty adult dogs, recently euthanased for unknown reasons, were obtained by the Department of Veterinary Anatomy during a period of 39 days, and were used in this study (**Table 1**).

At the arrival at the Department of Veterinary Anatomy, an approximate weight of each cadaver was obtained, in order to select dogs between 15 kg and 35 kg. Next, a standard ventrodorsal radiographic view of the pelvis, with the hips extended, was taken of each dog. Those cases which showed any osteoarthritic changes to the hip joint were eliminated from this study, and only skeletally mature dogs were selected, i.e., those which showed a complete fusion of the femoral head and greater trochanter epiphyses.

2.3.2. Dissection of the Hemipelves

Each hemipelvis was dissected of all soft tissues, other than the joint capsule and the teres ligament, in the manner which follows:

(i) Two skin incisions were made. The first was centred on the cranial aspect of the greater trochanter, from near the midline and, followed the cranial border of the femur to its distal third. A second skin incision was made, extending from the centre of the iliac crest, then passing just proximal to the greater trochanter (thereby crossing the first incision) and ending caudal and distal to the ischiatic tuberosity.

(ii) The subcutaneous tissues were reflected with the skin. An incision was made in the superficial leaf of the fascia lata along the cranial border of the biceps femoris muscle.

(iii) The sacrotuberous ligament was cut through its caudal third and the biceps femoris muscle was freed from its origin on the lateral angle of the ischiatic tuberosity, and reflected distally. Next, the internal obturator muscle was incised, as it passes behind the ischiatic spine, the gemelli muscles were freed from their origin on the lateral surface of the ramus of the ischium, and both muscles were cut loose through the tendons of insertion in the trochanteric fossa together with the insertion of the external obturator muscle.

(iv) The semitendinosus, semimembranosus, and the quadratus femoris muscles were freed from their origins on the caudal and ventrolateral parts of the ischiatic tuberosity, followed by the most lateral portion of the origin of the external obturator muscle on the ventral surface of the ischium. The quadratus femoris muscle was then freed from its caudal insertion immediately distal to the trochanteric fossa, together with the tendon of insertion of the adductor longus muscle which covers the end of the former muscle.

Specimen	Breed	Sex	Weight (kg)	Surgical procedure
1.- R	German shepherd	M	30	Control
1.- L				Transarticular pin
2.- R	Mongrel	M	25	Transarticular pin
2.- L				Control
3.- R	Mongrel	M	20	Control
3.- L				Transarticular pin
4.- R	Mongrel	M	18	Capsulorrhaphy
4.- L				Control
5.- R	Mongrel	M	17	Capsulorrhaphy
5.- L				Control
6.- R	German shepherd cross	M	30	Capsulorrhaphy
6.- L				Control
7.- R	Mongrel	M	20	Control
7.- L				Toggle pin
8.- R	Rottweiler	M	32	Toggle pin
8.- L				Control
9.- R	Mongrel	M	22	Control
9.- L				Transarticular pin
10.- R	Greyhound	F	20	Toggle pin
10.- L				Control
11.- R	Whippet	F	15	Control
11.- L				Transarticular pin
12.- R	German shepherd	M	30	Control
12.- L				Capsulorrhaphy
13.- R	Mongrel	M	20	Dorsal capsular prosthesis
13.- L				Control
14.- R	Mongrel	F	18	Control
14.- L				Dorsal capsular prosthesis

Table 1. Identification of the specimens and the surgical procedures used.

Specimen	Breed	Sex	Weight (kg)	Surgical procedure
15.- R	German shepherd	M	28	Control
15.- L				Dorsal capsular prosthesis
16.- R	German shepherd	M	30	Control
16.- L				Dorsal capsular prosthesis
17.- R	Greyhound	M	26	Control
17.- L				Toggle pin
18.- R	Greyhound cross	F	28	Dorsal capsular prosthesis
18.- L				Control
19.- R	German shepherd	F	22	Toggle pin
19.- L				Control
20.- R	Doberman cross	F	18	Capsulorrhaphy
20.- L				Control

Table 1. (cont.) Identification of the specimens and the surgical procedures used.

(v) Next, the femoral shaft was dissected of the muscle insertions of the pectineus and the adductor magnus et brevis muscles caudally, the iliopsoas muscle was transected at its insertion on the lesser trochanter, and the vastus medialis muscle was freed from its craniomedial origin on the intertrochanteric crest.

(vi) The tendon of insertion of the superficial gluteal muscle was then transected at the third trochanter, and the muscle was reflected dorsomedially. Next, the tendons of insertion of the middle gluteal and the piriformis muscles were cut off at the greater trochanter and both muscles were reflected dorsomedially. The deep gluteal muscle was dissected free from its insertion on the cranial aspect of the greater trochanter, and the muscle was then bluntly dissected dorsomedially from the joint capsule. Most times, the articularis coxae muscle was left in place attached to the joint capsule.

(vii) The vastus lateralis and vastus intermedius were then freed from their craniolateral origins on the proximal fifth of the femur.

(viii) The ventrolateral surface of the shaft of the ilium was exposed, for a distance of about 10 cm cranial to the acetabulum, by subperiosteal elevation of the caudal half origin of the iliacus muscle from the smooth ventral surface of the ilium, the tendon of origin of the rectus femoris muscle on the iliopubic eminence, and the caudal half origin of the deep gluteal muscle near the ischiatic spine.

(ix) Finally, blunt dissection was used to freed the medial shaft of the ilium, and the dorsal surface of the ischium was exposed by subperiosteal elevation of most of the origin of the internal obturator muscle, close to the obturator foramen.

2.3.3. Surgical Procedures

From every dog, a normal hip, dissected of all soft tissues other than the intact joint capsule and teres ligament and, in most cases, the articularis coxae muscle, was used as a **control**, **(Figures 1 and 2)**. The contralateral dissected hip was dislocated by a circumferential incision of the joint capsule and transection of the teres ligament, and subsequently reduced by one of the following four methods of stabilization: Capsulorrhaphy, transarticular pin, dorsal capsular prosthesis, and toggle pin technique. Every technique was performed in five different cadavers.

The assignment of any one technique to any one dog was based on the instruments and materials which were assembled at any one time, and it did not take into account the size of the dogs. The 20 operations performed were evenly divided between the right and left hemipelves.

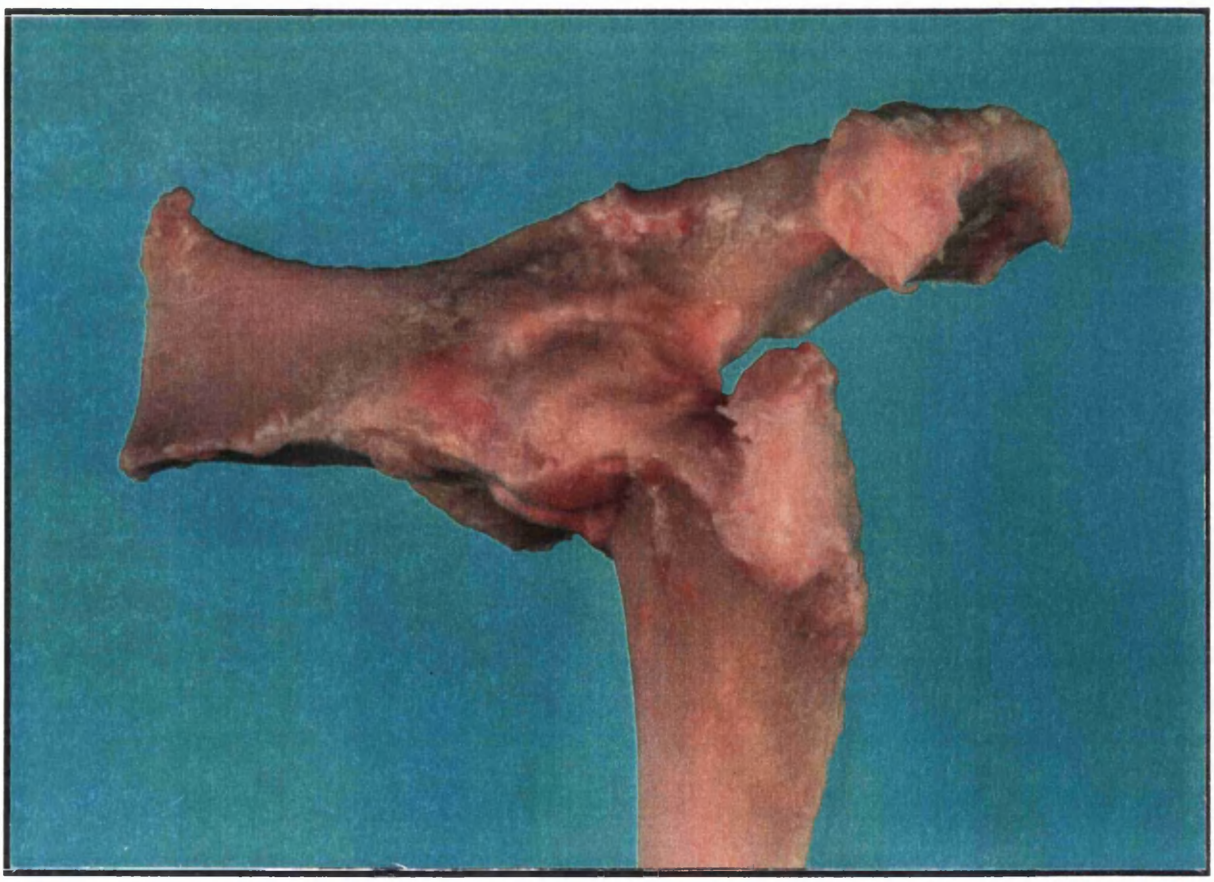

Figure 1. Control group (lateral view of left hip).

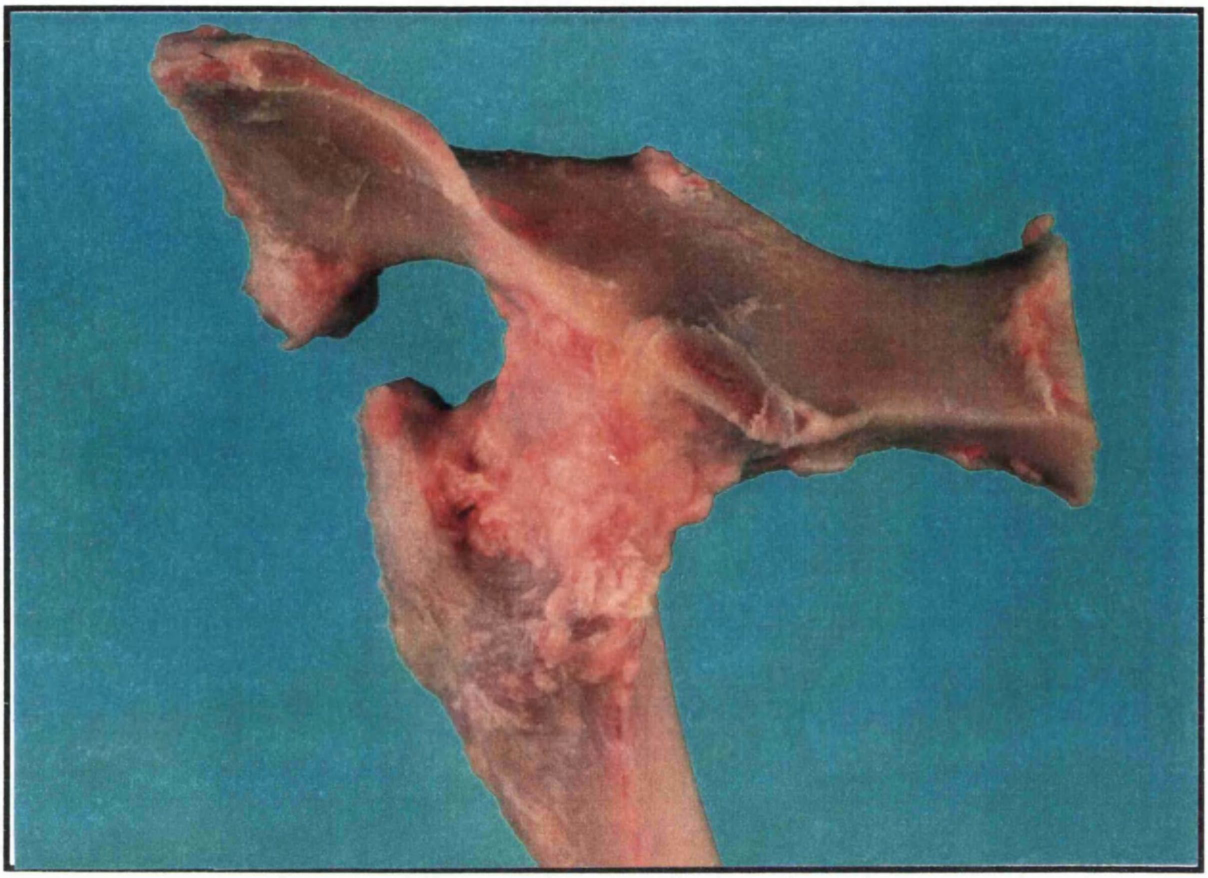

Figure 2. Control group (medial view of left hip).

2.3.3.1 Capsulorrhaphy

On average, 12 horizontal mattress sutures, of 3 metric polydioxanone monofilament synthetic absorbable material (PDS* II, Ethicon, Edinburgh), were placed along the circumferential incision of the joint capsule (**Figures 2 and 3**). Throughout this procedure, the leg was held in slight abduction in order to facilitate the imbrication of the joint capsule.

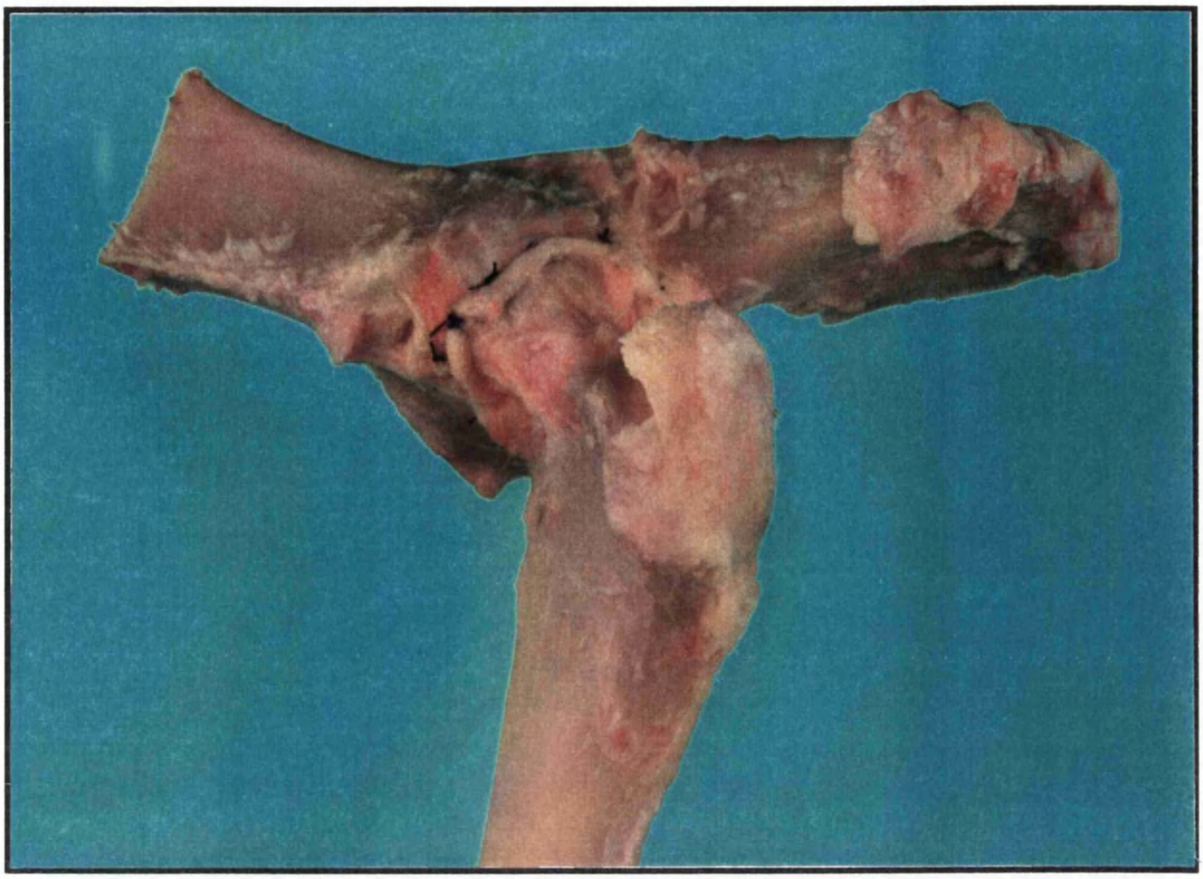

Figure 3. Capsulorrhaphy (lateral view of left hip).

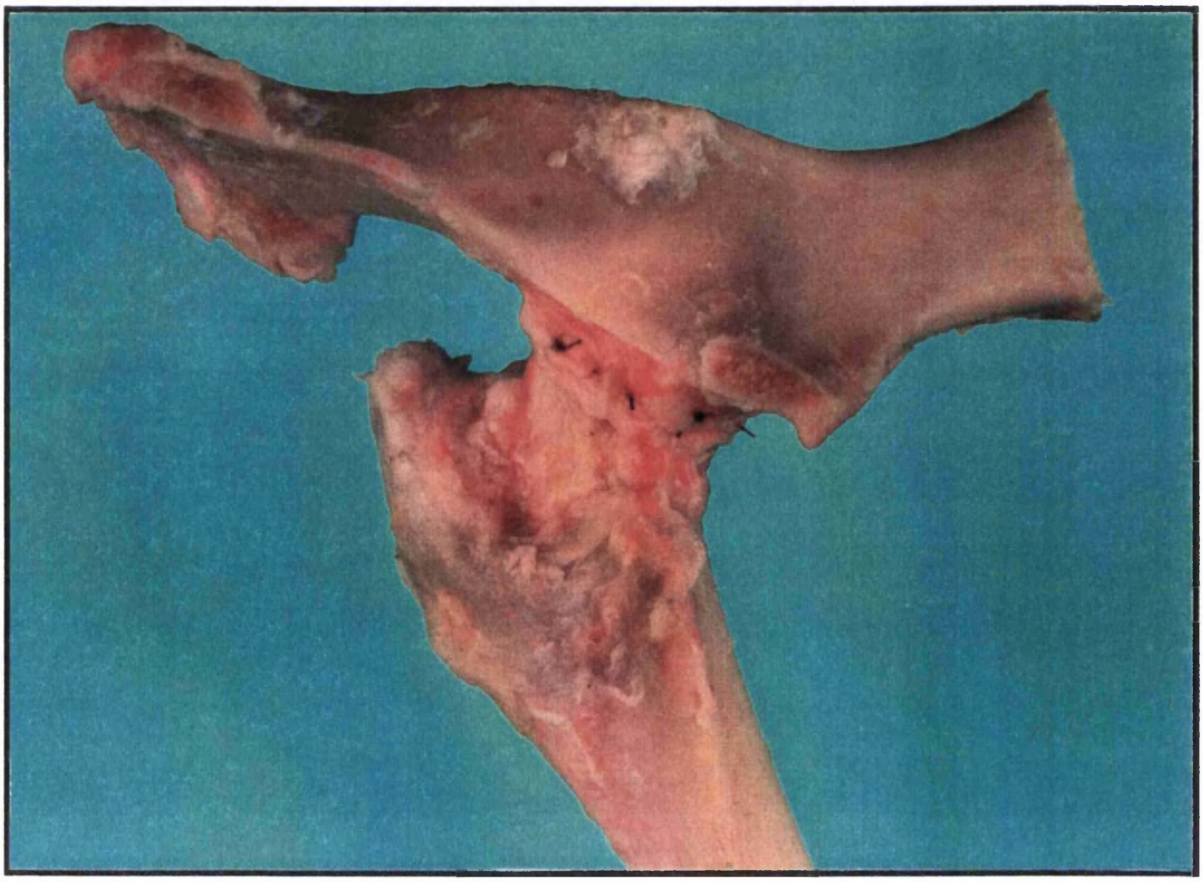

Figure 4. Capsulorrhaphy (medial view of left hip).

2.3.3.2 Transarticular pin

The technique which was used was similar to the one described by Gendreau and Rouse (1975), but took into consideration Aron and Toombs (1984) recommendation of predrilling with a drill bit smaller than the pin, in order to accomplish smooth and precise pin insertion and to limit excessive temperature elevations.

An electric drill (Black & Decker, BD561/H1A, 2500/rpm) was used. Using a 2.5 mm drill bit, a hole was drilled, in a retrograde fashion, from the fovea capitis, through the femoral head and neck, to emerge approximately 1 cm distal to the greater trochanter. The hip was then reduced and the limb held slightly abducted while the drill was again used, in a normograde fashion, through the predrilled tunnel and through the acetabular fossa into the pelvic canal.

Finally, a Jacob's chuck was used to insert a 2.7 mm Steinmann pin, in a normograde fashion, until it protruded into the pelvic canal by about 1 cm. The hand chuck was then used to bend the pin at its free end, and the excess length of pin was cut off (**Figures 5 and 6**).

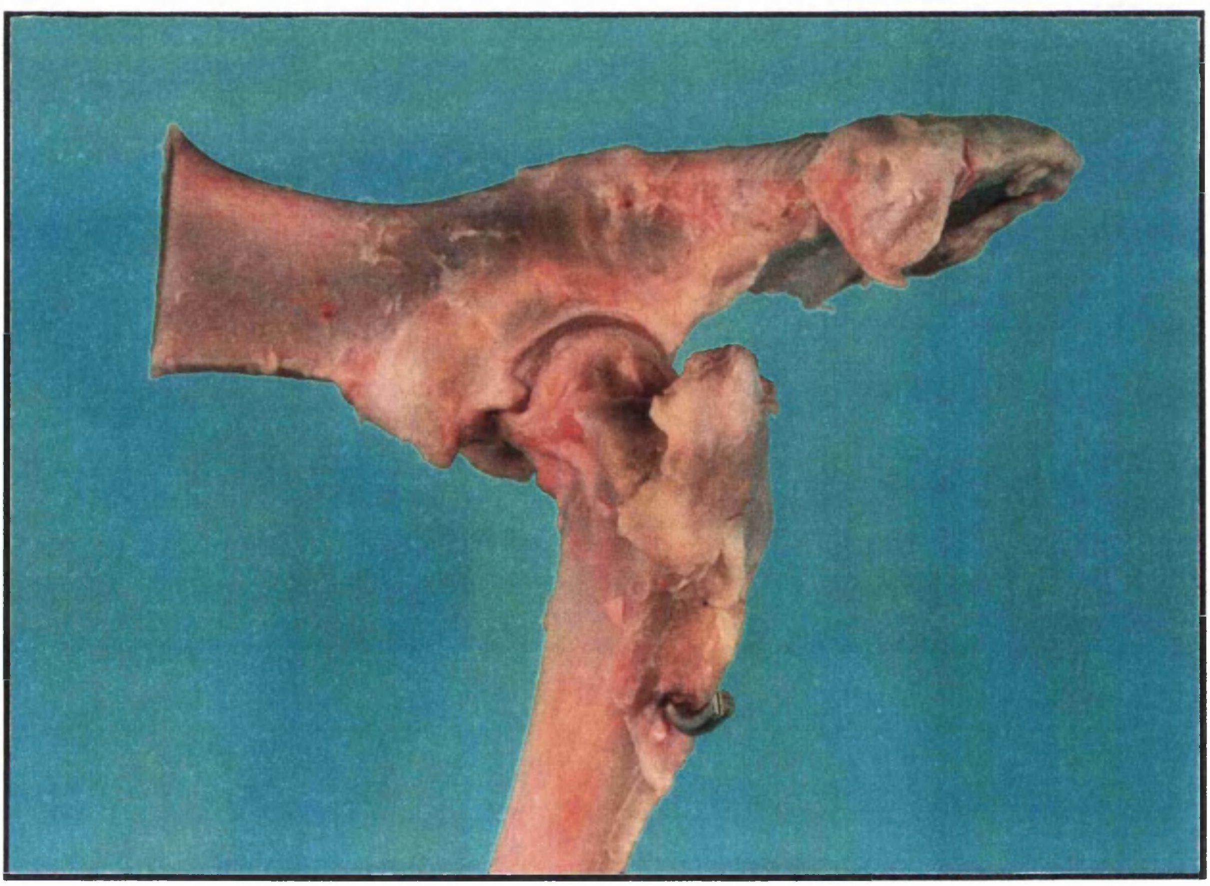

Figure 5. Transarticular pin (lateral view of left hip).

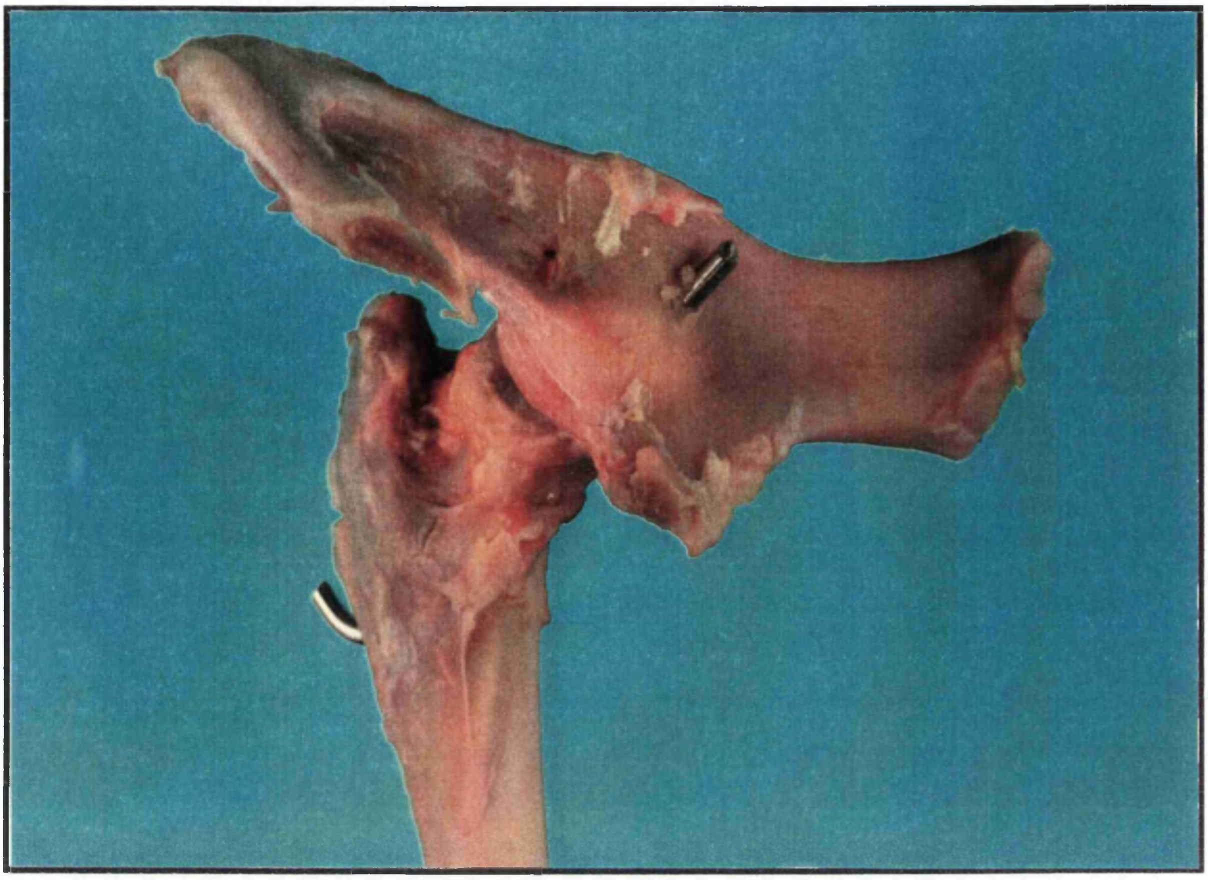

Figure 6. Transarticular pin (medial view of left hip).

2.3.3.3 Dorsal capsular prosthesis

The technique which was used was that described by Allen and Chambers (1986). A 2.5 mm drill bit was used to drill two holes in the dorsal acetabular rim, at the 10 and 1 o'clock positions for the left hip and the 11 and 2 o'clock positions for the right hip. The depth of the two holes was measured by means of an orthopaedic depth gauge, the holes were then tapped, followed by the partial insertion of two 3.5 mm cortical screws with metal washers.

Using a 2.5 mm drill bit, a transverse tunnel was drilled through the femoral neck, cranial to caudal, just medial and distal to the greater trochanter.

The luxation was then reduced and, with the leg held in slight abduction, two lengths of 5 metric braided polyester suture material coated with polybutylate (Ethibond*, Ethicon) were threaded through the bone tunnel by means of a wire loop, separated and then each suture was placed around a screw, under the washer, and tied tight. Finally, the two screws were fully inserted (**Figures 7 and 8**).

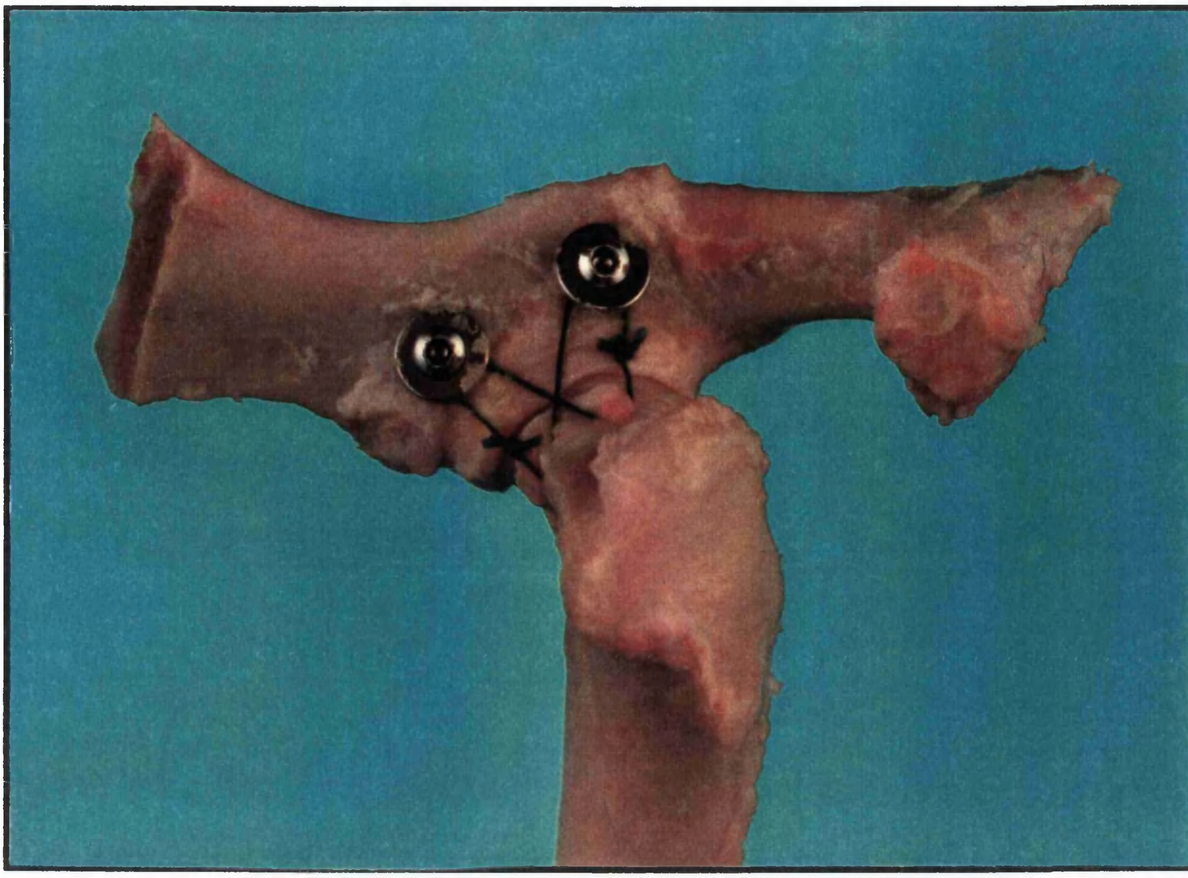

Figure 7. Dorsal capsular prosthesis (lateral view of left hip).

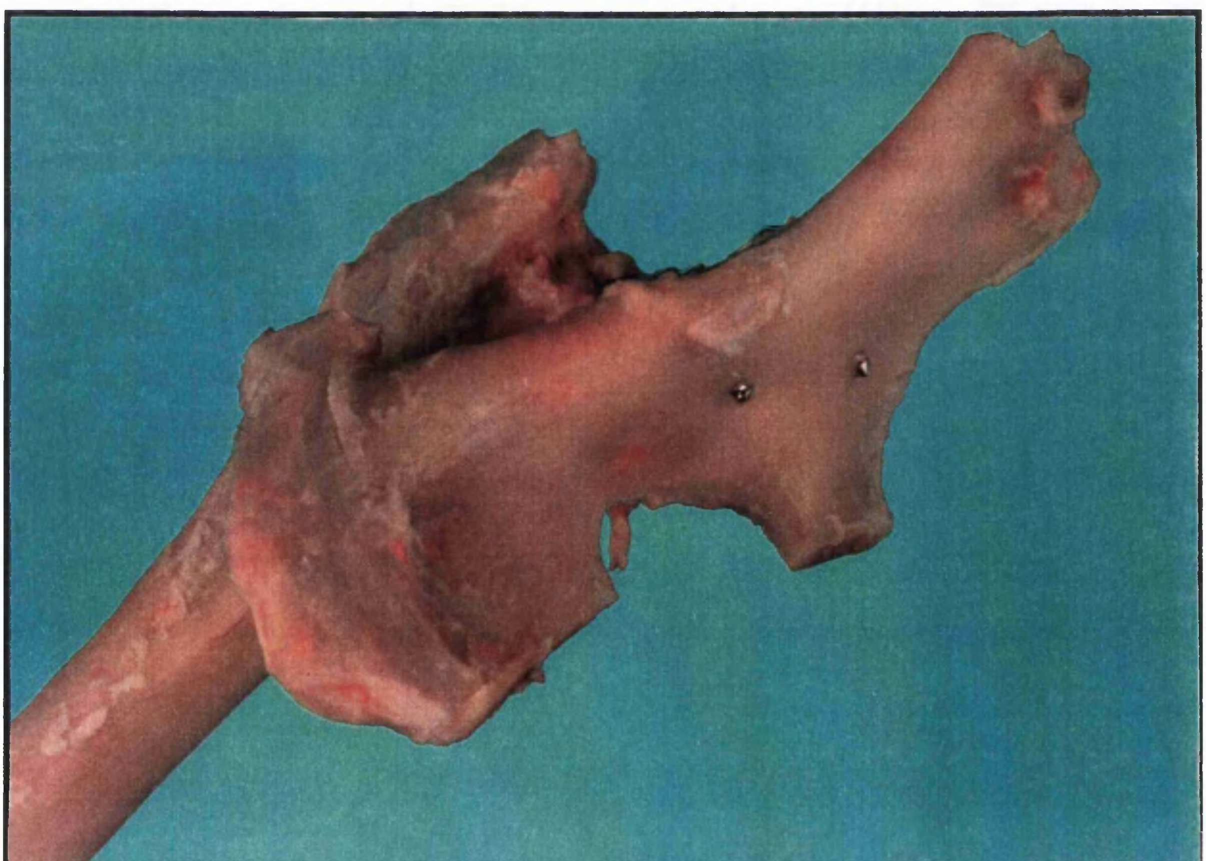

Figure 8. Dorsal capsular prosthesis (medial view of left hip).

2.3.3.4 Hip toggle pinning

The technique which was used was that described by Brinker and others (1990). Using a 2.5 mm drill bit, a hole was drilled from the fovea capitis, through the femoral head and neck, to emerge about 2 cm distal to the greater trochanter. A second tunnel was drilled in a craniocaudal direction, just dorsal to the first tunnel. Next, using a 4.7 mm drill, a hole was drilled through the acetabular fossa.

A 1.3 cm long toggle pin was made out of 1.1 mm Kirschner wire, according to Piermattei (1965[b]). Two strands of 5 metric braided polyester suture material coated with polybutylate (Ethibond*, Ethicon) were threaded through the toggle pin. While the femoral head was still dislocated, the toggle pin was held in forceps and pushed through the acetabular hole, and the ends of the suture were pulled until the toggle pin eventually turned 90 degrees and sat against the medial cortex of the acetabulum. All four ends of the sutures were then pulled through the bone tunnel using a wire loop, the sutures were pulled tight, the hip was reduced, and one set of sutures was passed through the proximal bone and tied to the other suture set (**Figures 9 and 10**).

Figure 9. Hip toggle pinning (lateral view of right hip).

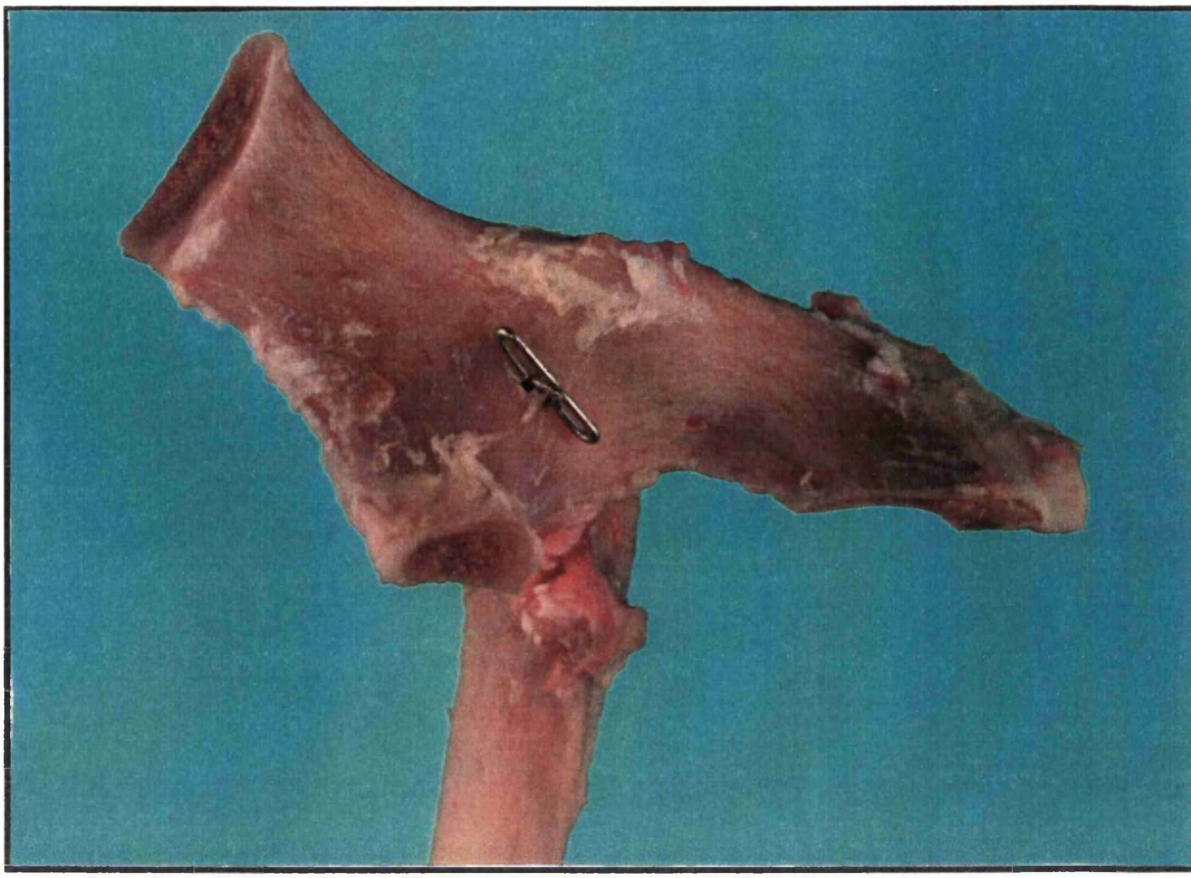

Figure 10. Hip toggle pinning (medial view of right hip).

2.3.4. Storage of Specimens

After each procedure, an electric oscillating saw (Zimmer Orthopaedic Ltd., Bridgend, Britain) was used to cut each hemipelvis to an appropriate size for testing. The femoral shaft was cut across its distal third; the body of the ilium was cut transversally, at the level of the caudal aspect of the sacroiliac joint; next, the ischium was cut longitudinally from the obturator foramen towards the caudal part of the ischium; finally, the pubic bone was cut longitudinally, close to the acetabulum.

Each specimen was then washed under running water for about 5 minutes, and it was then wrapped in a paper towel, soaked in physiological saline, put inside a sealed plastic bag, and stored in a deep freeze at -20°C. Roe, Pijanowski and Johnson (1988) advocated that canine bone, aseptically collected, did not undergo significant structural alterations after 16 and 32 weeks of sterile storage at -20°C.

Although these specimens were not aseptically processed, it was assumed that their biomechanical properties would not be detrimentally affected.

2.3.5. Mounting of the Specimens

Prior to testing, the specimens were defrosted overnight and square metal tubing (2.5 cm x 2.5 cm) was mounted into each one.

An electric oscillating saw (Zimmer Orthopaedic Ltd.) was used to cut a bone groove on the body of the ilium and another one on the ischium, in order to accommodate the placement of two 3 cm long pieces of tubing, one at each end, parallel to the acetabular rim. A commercial car filler, made out of a paste and a resin hardener (Isopon P38, W. David & Sons Ltd., Northants) was used to grout the tubing to the bone specimens. A 6.5 cm piece of tubing was placed enclosing the distal shaft of the femur, perpendicular to the vertical plane made by the other two pieces of tubing, and it was similarly fixed to the bone (**Figure 11**).

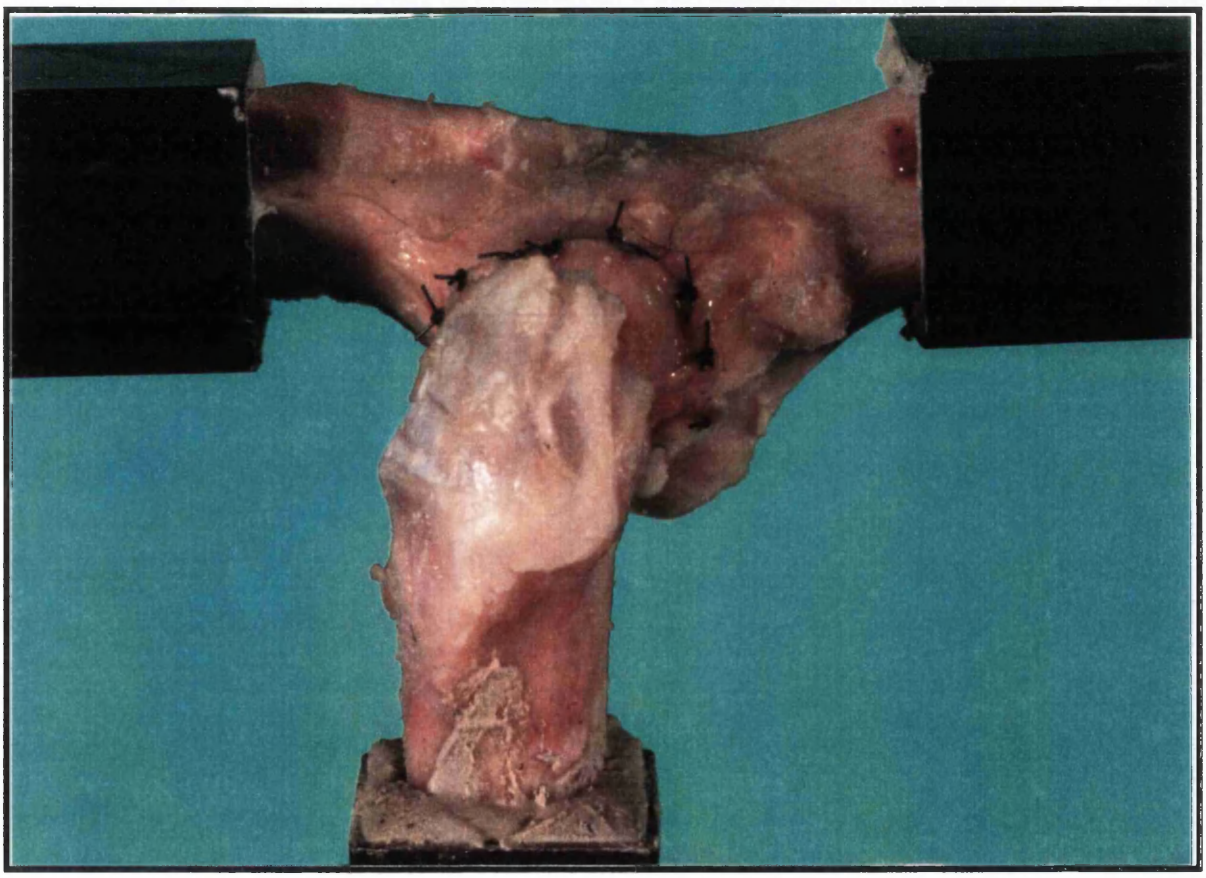

Figure 11. Mounted capsulorrhaphy specimen (lateral view of right hip).

A modification had to be made on the 5 transarticular pin specimens due to their locked joint, which prevented abduction and adduction of the femur. The two small pieces of tubing, on the ilium and ischium, could not be placed parallel to the acetabular rim (which was slightly rotated inward), so that the shaft of the femur could still, in the end, be parallel to the horizontal plane made by the two small pieces of tubing (**Figure 12**). The mounted specimens were again kept frozen at -20° C while waiting to be tested.

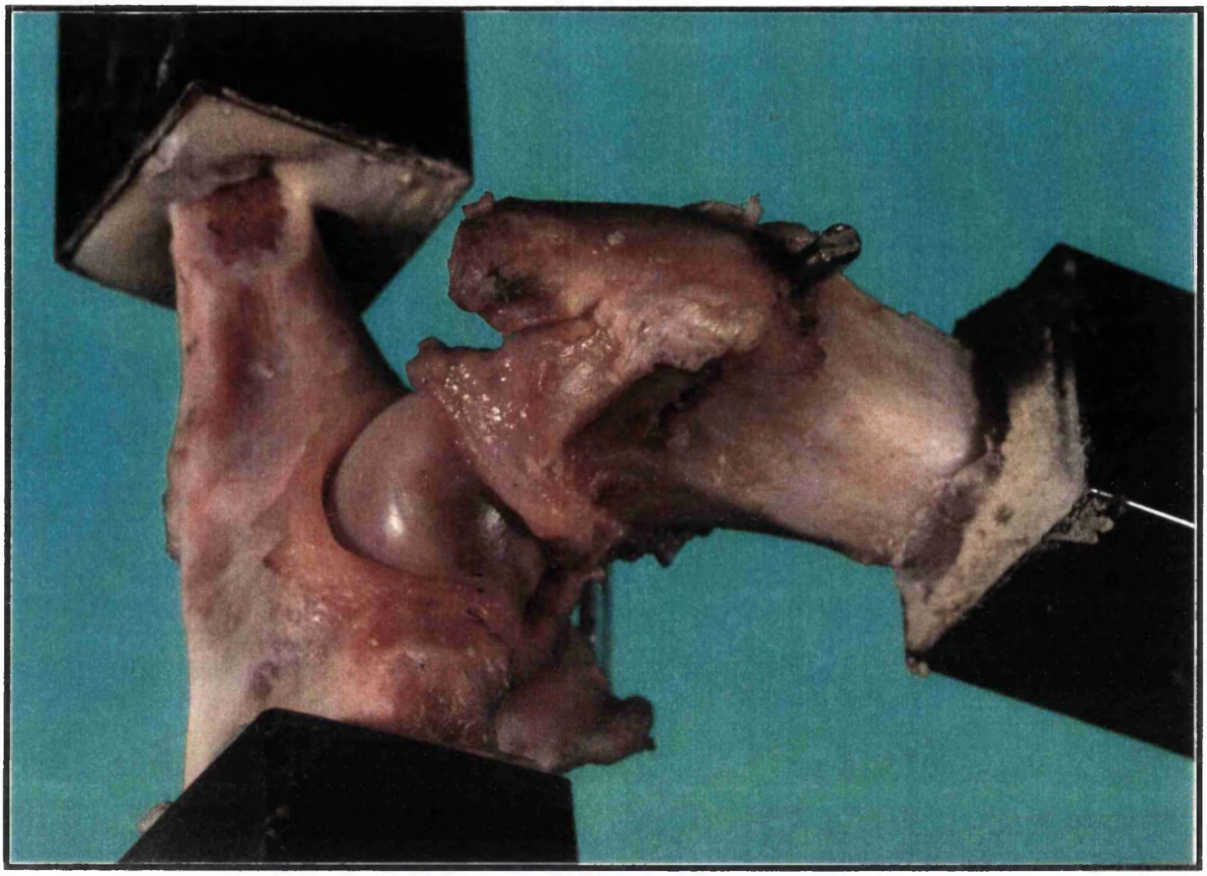

Figure 12. Mounted transarticular pin specimen (craniodorsal view of left hip).

2.3.6. Testing of the Specimens

The specimens were defrosted at room temperature prior to testing. Testing took place at the Department of Bioengineering of Strathclyde University, using a INSTRON 4505 machine (Instron Testing Machine, Model 4505, Instron, USA), with load strain control, which ran using a Series IX cyclic testing software.

The INSTRON 4505 has a rigid reinforced base with a robust box-beam moving crosshead for high stiffness and precise alignment throughout the test, regardless of load. The crosshead is kinetically balanced on dual bearings to assure precise alignment (**Figure 13**).

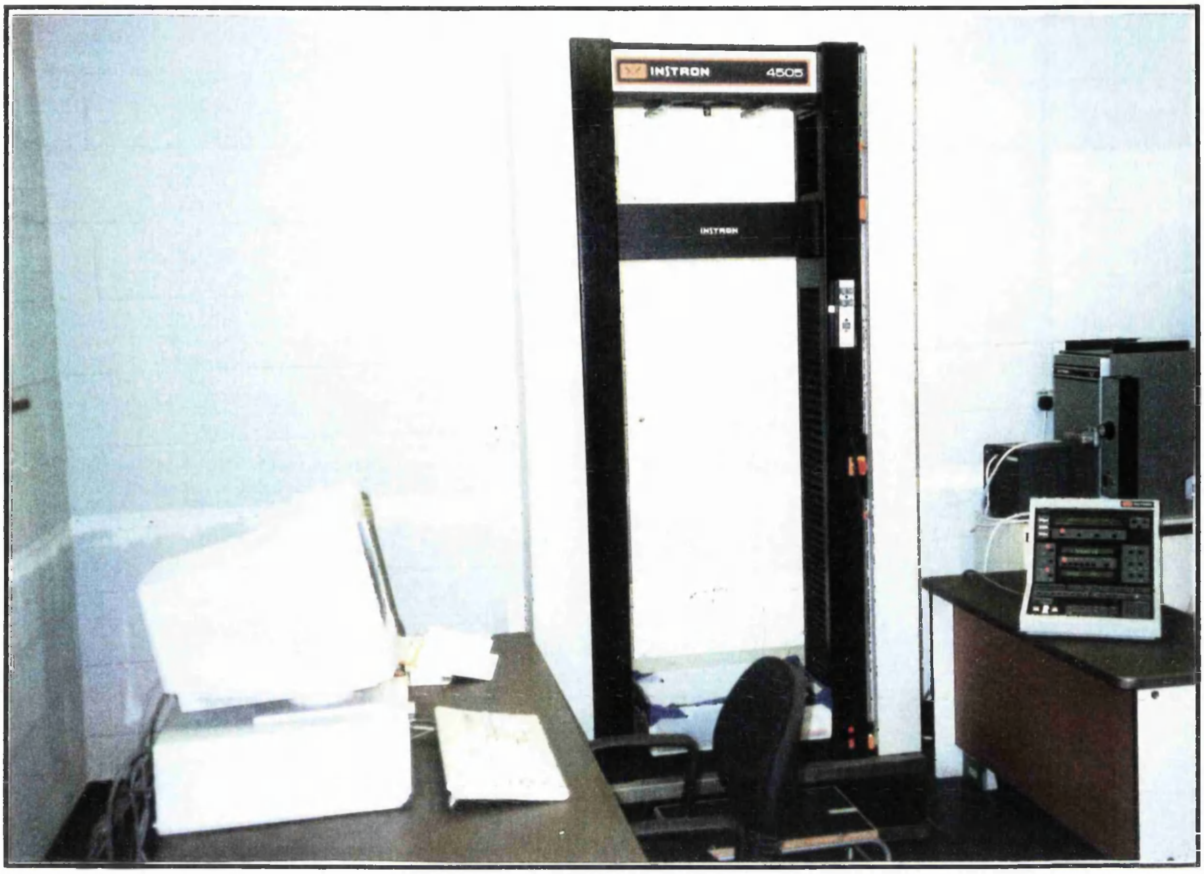

Figure 13. Instron 4505 testing machine connected to cyclic testing software.

Each specimen was attached to the movable crosshead by the two pieces of tubing fixed to the pelvic bone, while the piece of tubing around the femur was attached to the rigid base of the machine. All specimens were tested with the femoral shaft fixed at approximately 9° to the horizontal plane of the pelvic fixation (**Figure 14**), except for the transarticular pin specimens, which were mounted with the femoral shaft parallel to the horizontal plane of the pelvic fixation.

Load (kN) was tested against displacement (mm). The machine was set up at:

(i) Constant rate of displacement of 10 mm/min.

(ii) Sampling rate of 10 points/second.

A load displacement curve was computer generated for each specimen. Figures 15 to 21 show such curves. The scale of the axis for displacement is not the same for each figure, but that did not seem relevant because the rate of displacement was the same for every specimen. The load displacement curves were used to obtain mean values for ultimate (failure) strength (peak load) from each group of procedures. Failure was defined as occurring when a peak load was followed by a drop of over 20%. The mode of failure was recorded for each specimen.

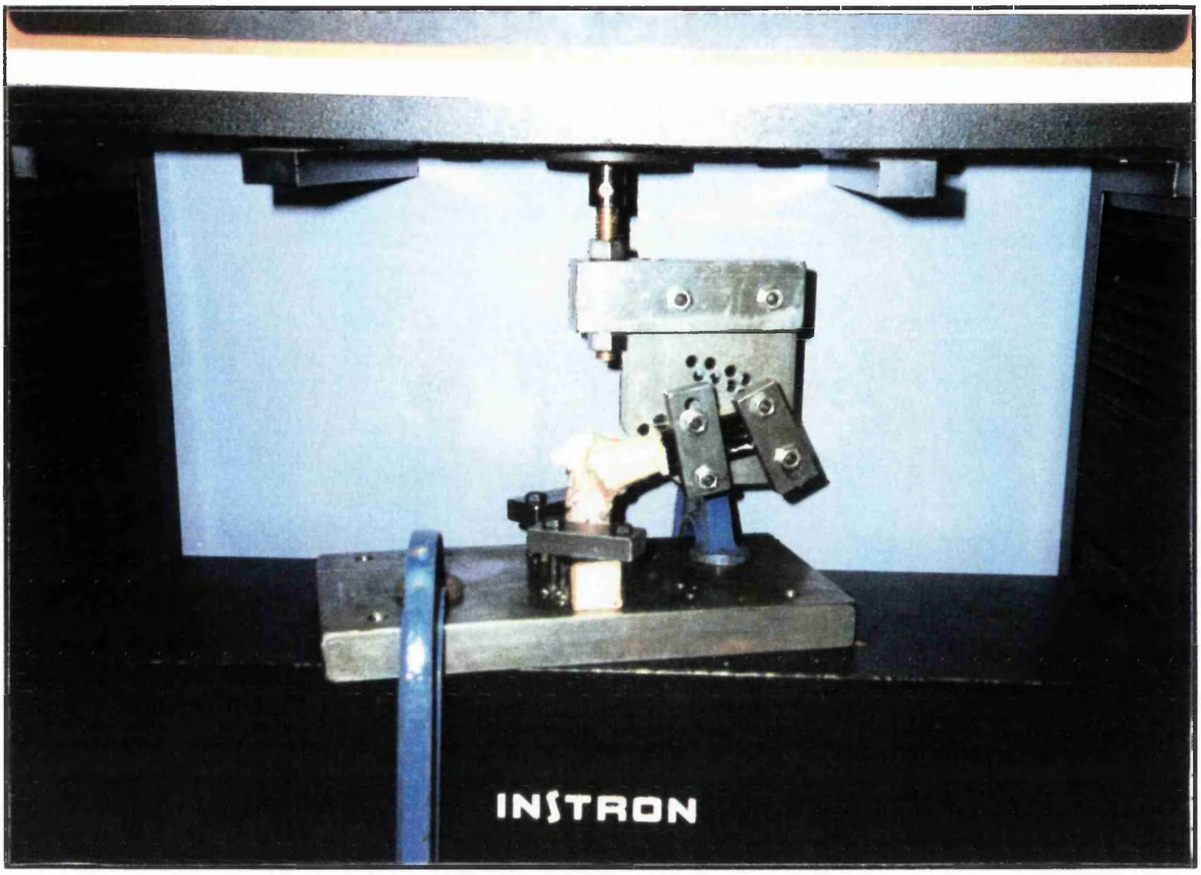

Figure 14. Testing of one of the control specimens.

Each group was analysed separately. The control group was analysed as two different groups, namely for the right and left hips, and two peak loads were recorded corresponding to the initial capsular failure and total failure of the capsule and teres ligament.

The computer software connected to the testing machine recorded the peak load and the displacement at peak of each individual test, and calculated the mean, the standard deviation and the coefficient of variance from each group.

A one-way analysis of variance (ANOVA) test was used to compare the results of peak load between the four surgical techniques, between the four surgical groups and the control group (considering the control as a single group), and between the control right and the control left; differences with a probability value < 0.05 were considered statistically significant.

3. Results

3.1. Capsulorrhaphy

The five capsulorrhaphy specimens consistently failed through the sutured circumferencial incision due to the sutures cutting through the joint capsule. Three of the specimens failed caudodorsally and two craniodorsally. The peak loads at failure ranged between 14.6 kg and 33.3 kg (**Figure 15**).

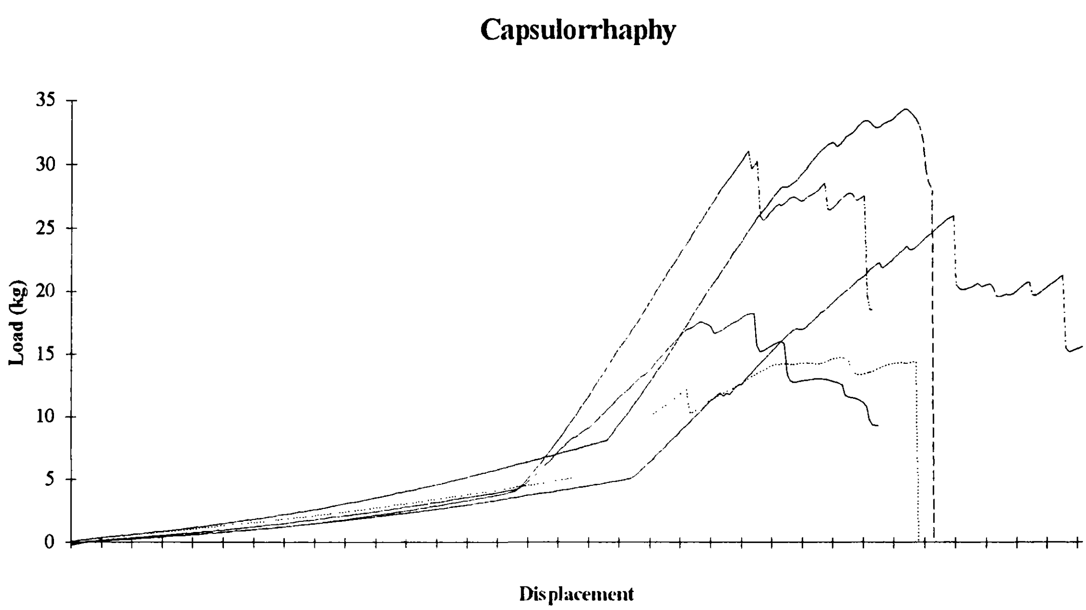

Figure 15. Graphic behaviour of the 5 capsulorrhaphy specimens.

3.2. Transarticular pin

All specimens failed similarly with the pin being pulled out fairly easily (with peak loads at failure ranging from 2.7 kg to 10.9 kg), except for one of the specimens which failed at a peak load of 20.7 kg (**Figure 16**).

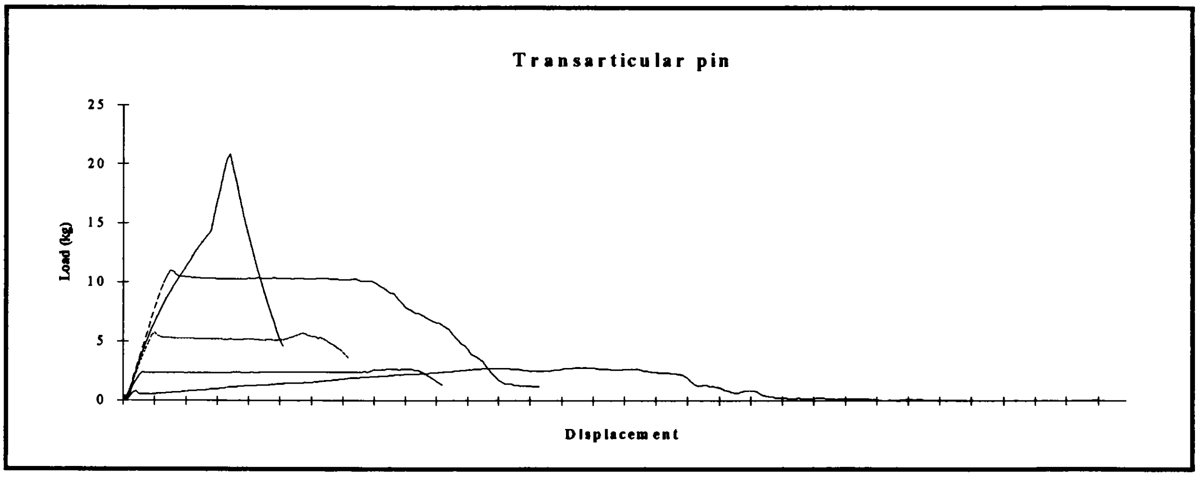

Figure 16. Graphic behaviour of the 5 transarticular pin specimens.

The reason for such an odd behaviour from one of the specimens is the fact that the pin was placed through the acetabular fossa at more of an acute angle, as compared to the rest of the specimens.

3.3. Dorsal capsular prosthesis

All five specimens failed due to breakage of the suture material, through the caudal attachment in three cases, and through both attachments and the cranial attachment in one case each. The peak loads at failure ranged between 22.4 kg and 29.1 kg (**Figure 17**).

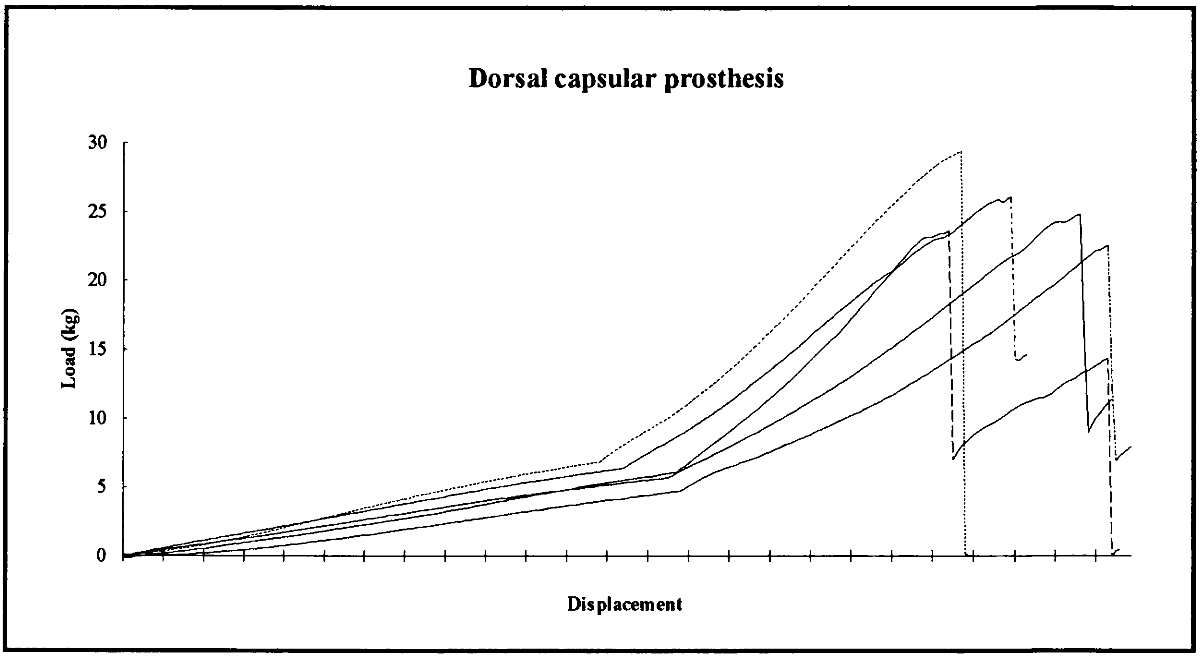

Figure 17. Graphic behaviour of the 5 dorsal capsular prosthesis specimens.

3.4. Hip toggle pinning

All specimens failed due to bending of the toggle pin in the middle, and subsequently being pulled through the tunnel in the acetabular fossa. The peak loads at failure ranged between 15.7 kg and 27.3 kg (**Figure 18**).

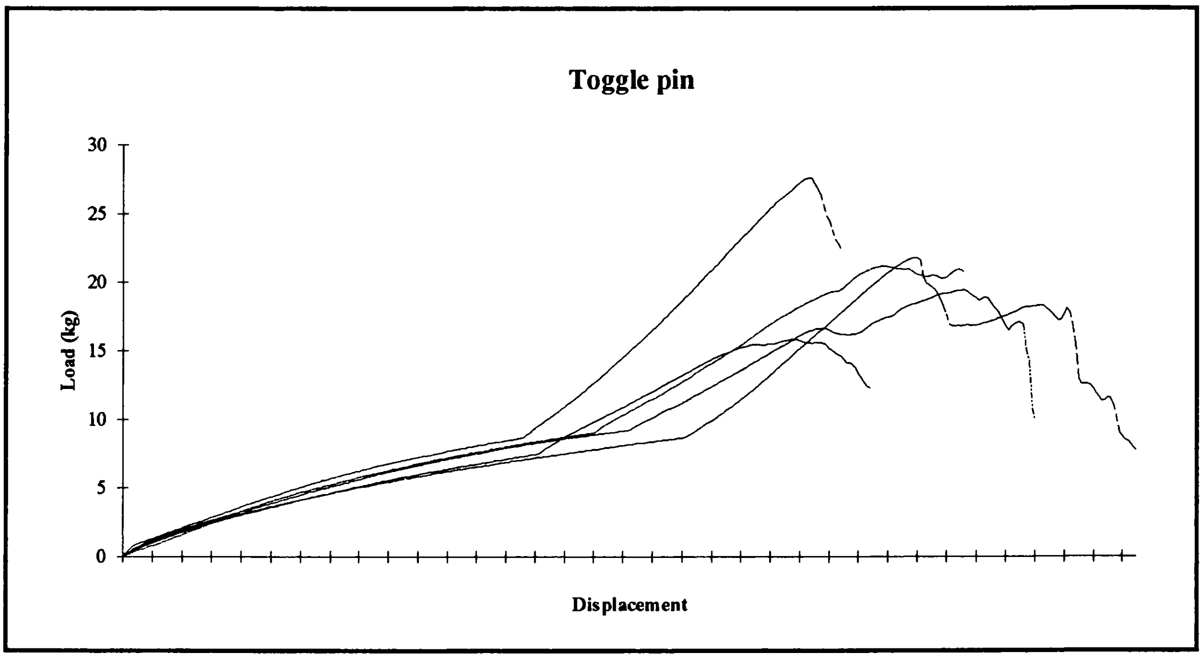

Figure 18. Graphic behaviour of the 5 hip toggle specimens.

3.5. Control group

Three of the specimens of the control group of the right hip had to be excluded due to problems which arose during the recording of the test.

All seventeen control group specimens behaved similarly in that they all had a first failure point related to the initial rupture of the joint capsule (usually so small that it could not be visualised), after which the load would steadily increase ut to a peak load failure coinciding with the snapping of the teres ligament, immediately followed by the final rupture of the joint capsule. All joint capsule ruptures occurred along its femoral insertion.

All seven control specimens of the right hip failed along the dorsal insertion of the joint capsule. The peak loads at failure ranged between 49.1 kg and 88.7 kg (**Figure 19**).

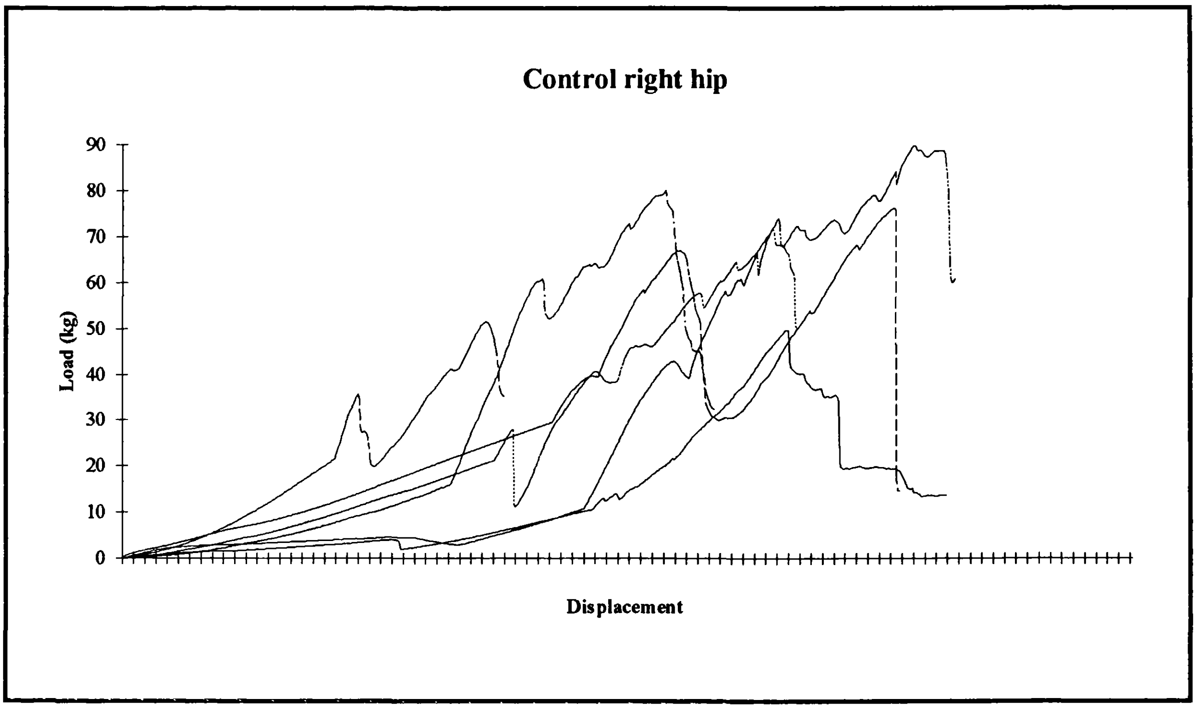

Figure 19. Graphic behaviour of the 7 control specimens of the right hip.

All but one of the ten control specimens of the left hip failed through rupture of the dorsal aspect of the joint capsule, the exception being through primary rupture of the ventral aspect of the joint capsule. The peak loads at failure ranged between 34 kg and 83.4 kg (**Figure 20**).

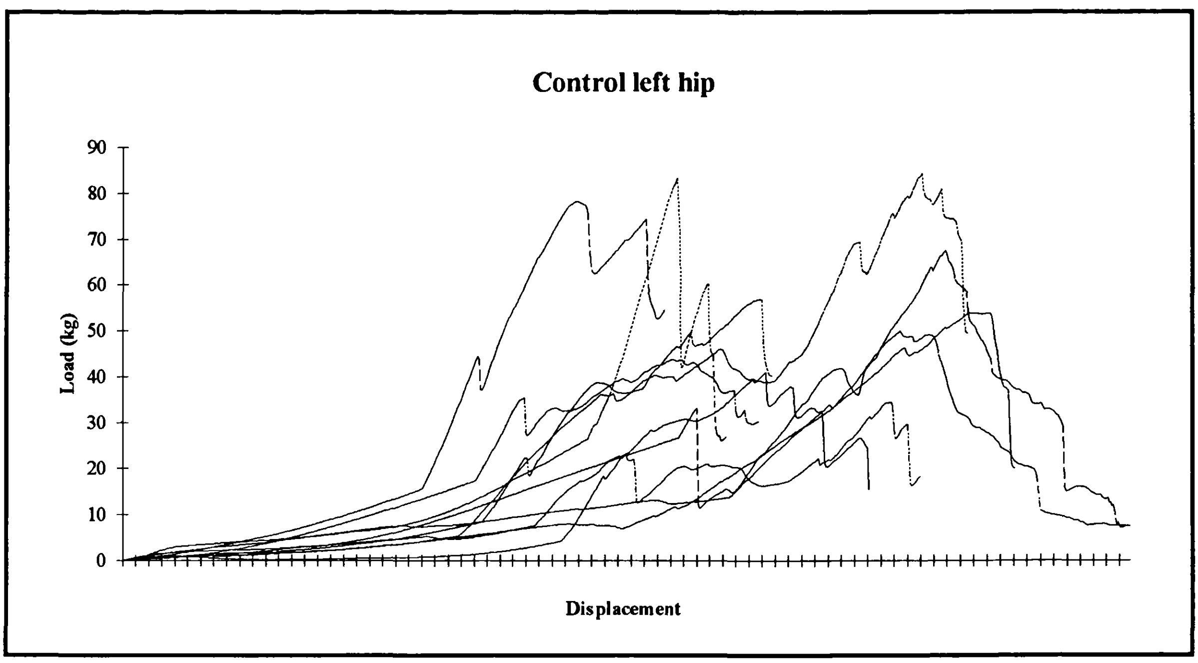

Figure 20. Graphic behaviour of the 10 control specimens of the left hip.

From each test group a curve was obtained from the mean values of every point (**Figure 21**). Although these curves have been subject to some odd values, they still reflect the general behavioural pattern of each test.

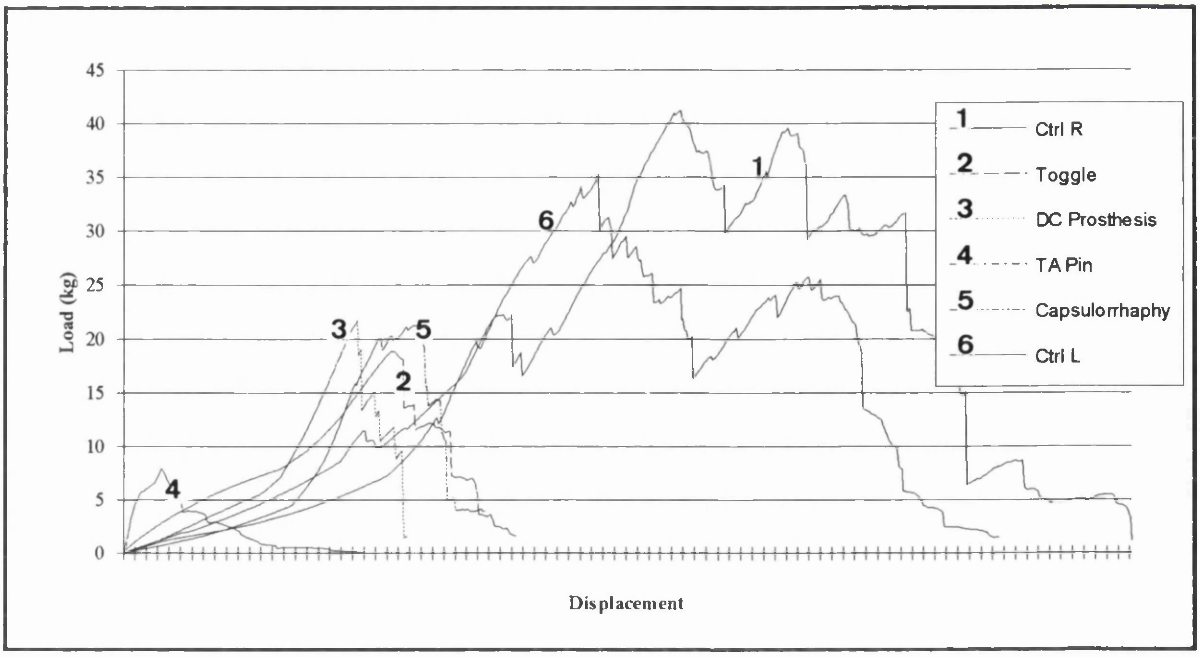

Figure 21. Mean curves of the six tests.

3.6. Peak load failure among different groups

The mean peak load at failure of the four surgical groups and the mean initial failure and peak load at failure of the control groups of the right and left hips are shown (**Figure 22**).

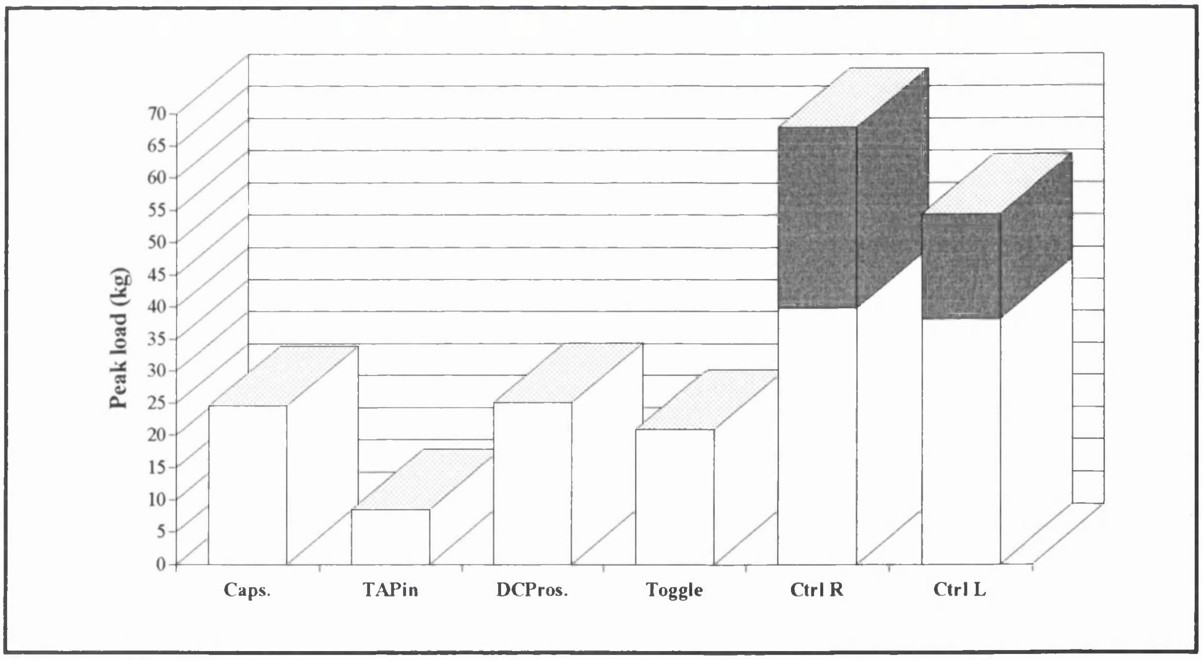

Figure 22. Mean peak load at failure of the different groups.

The mean peak load of the transarticular pin group (8.54 kg) was significantly weaker than the other three surgical techniques which had mean peak loads of 25.1 kg (dorsal capsular prosthesis), 20.9 kg (toggle pin), and 24.6 kg (capsulorrhaphy).

The combined control group (right and left hip) had a mean peak load of 59.9 kg, which was significantly stronger than the mean value for the four surgical techniques (19.79 kg).

The peak load of the control group of the right hip (67.8 kg) was not significantly different from that of the control group of the left hip (54.4 kg).

4. Discussion

The resistance to lateral displacement of the femoral head of four methods used currently in the treatment of coxofemoral dislocations has been compared. In order to reflect the population at risk, hips were obtained from skeletally mature dogs. To exclude joint quality as a source of error, radiographs of the pelvis were taken prior to the preparation of each specimen and those cases which showed any osteoarthritic changes were rejected. The experimental conditions differed from the clinical situation in several important regards.

First of all, the bone specimens were bare of any muscular support. Smith and others (1990) stressed the importance of the periarticular musculature in more effectively limiting the lateral displacement of the femoral head, indicating that beyond the joint capsule, other periarticular structures, by virtue of their fluid-like mass and resistance to displacement, contribute to the hydrostatic constraint by transmission of a continuous pressure gradient from the sub atmospheric pressure in the synovial fluid to the atmospheric pressure outside the dog. Their findings were proven true even in the cadaver muscle in a non contractile state. Moreover, each intrinsic muscle of the normal hip during weight bearing is anatomically oriented to generate a resolved force component, an active force component, which tends to seat the femoral head firmly into the acetabulum.

Last but not least, under *in vivo* conditions any technique aims at reducing the dislocation and stabilizing the joint sufficiently to allow soft tissue healing. Once the healing is complete, the anatomic shape of the hip joint and fibrosis of the joint capsule hold the hip in place (Tomlinson, 1990). The joint capsule and the teres ligament appear to heal completely by about two months after surgery (Dobbelaar, 1963).

It is obvious from the great number of surgical techniques which have been described in the literature, that coxofemoral dislocation can present difficulties in the manner of reduction and maintenance (Campbell and others, 1968). It reflects the lack of consistently good results by any one method (Stead, 1970).

Results of the various techniques are hard to compare because of the variation in patient selection, criteria for evaluation, and the lack of reported results for some techniques. Well documented studies report variable success rates. Care must be taken in their interpretation. It is important to differentiate between success in maintaining reduction and success in restoring acceptable limb function (Johnson and Braden, 1987). However, judging from the results which have been published, one can expect clinical success rates ranging between 65% and 85%, being 74% (Gendreau and Rouse, 1975) to 80% (Hunt and Henry, 1985) for the transarticular pin, 65% (Johnson and Braden, 1987) for the dorsal capsular prosthesis, and 79% (Denny and Minter, 1973) to 84% (Denny, 1993) for the toggle pin technique.

The hypothesis of the project was that techniques that are very successful clinically, differ in resistance to the lateral displacement of the proximal femur (a necessary first step for redislocation to occur) and some of these techniques have considerably lower resistance than the normal intact supporting soft tissue structures of the joint.

Failure, during *in vitro* testing, was defined as occurring when the peak load was followed by a drop of over 20% during lateral displacement of the femoral head. This is a clinically significant point because it represents the onset of permanent deformation, in other words of luxation. The actual amount of displacement at peak load was recorded but not analysed because the specimens were tested at a fixed rate of displacement, and peak load was the parameter of primary interest.

The results of this test indicate that the control group was, not surprisingly, significantly more resistant to failure than the four surgical groups. There were no significant differences between the right and left control groups.

All but one of the seventeen control group specimens failed through rupture of the dorsal aspect of the joint capsule. This can be explained because it was this area of the joint capsule which was subjected to the greatest tension, due to the fact that the specimens were tested with the femoral shaft fixed at approximately 9° to the horizontal plane of the acetabulum. This angle is considerably smaller than the normal angle in a standing dog, which is about 45° in a dog with an angle of inclination of the femoral neck of 135°. There was only one specimen which failed along the ventral aspect of the joint capsule. All the capsulorrhaphy specimens also failed along the dorsal aspect of the joint capsule, possibly for the reasons stated above.

The fact that all control group specimens had a first failure point with a corresponding drop in load, related to the initial rupture of the joint capsule, followed by a steady increase in load until a final peak load failure occurred, coinciding with the snapping of the teres ligament, is explained by the findings of Smith and others (1990) who claimed that with the hip in a neutral position and the hydrostatic factor operating, the teres ligament is not a constraint to lateral displacement of the femoral head.

As expected, control hip specimens from heavier dogs had, generally, higher peak loads at failure than those from the lighter dogs.

The transarticular pin group was significantly weaker than any of the other surgical techniques. The mean peak load at failure for the transarticular pin technique was 8.54 kg. The values were all between 2.7 kg and 10.9 kg, except for one specimen, where the pin had been placed with the femur more abducted, which reached a peak load of 20.7 kg. This could support the clinical concept that the pin should be inserted with the leg slightly abducted.

There were no significant differences between the capsulorrhaphy group (mean peak load of 24.6 kg), dorsal capsular prosthesis (mean peak load of 25.1 kg) and the hip toggle group (mean peak load of 20.9 kg). All dorsal capsular prosthesis specimens failed through breakage of the suture material, while all hip toggle specimens failed due to bending of the toggle pin in the middle. The size of the suture material appeared to determine the mode of failure of the dorsal capsular prosthesis technique. The toggle pin could be made stronger by using a thicker Kirschner wire.

The clinical relevance of these findings is not known. When viewed against the mean peak load of the combined control group of the right and left hips (59.9 kg), the four surgical techniques (capsulorrhaphy, transarticular pin, dorsal capsular prosthesis and hip toggle pinning) are at best only 55.6%, 34.6%, 48.6% and 45.6% as strong, respectively. These results only identified the restrains at maximum *in vitro* forces *per se*. The active contribution of the secondary joint restrains, particularly of the muscle contraction forces, were absent.

According to Arnoczky and Torzilli (1981) the hip joint of the dog is subjected to loads much greater than the superimposed body weight. This is due, in part, to muscle action, especially abductor pull, which combines with the supported body weight and pelvic torque to exert the resulting force at the hip. The femoral head has been referred to as being trapped in a "nutcracker", with the body weight "squeezing" down while the muscle forces are "squeezing" up.

In a normal stance phase, the forces acting on the femoral head have, therefore, a totally different resultant component from the one which was used during this test.

Since there appears to be no significant differences in the clinical outcome between the surgical techniques described for dorsal coxofemoral dislocations, it seems appropriate to suggest that the reported success rates are mostly due to the intrinsic muscle forces acting upon the hip, thereby contributing to the maintenance of reduction.

We therefore suggest that the ultimate choice of any one technique used to stabilize dorsal coxofemoral luxations in the dog should be based on the surgeon's familiarity with the techniques, preferably one which does not interfere with the articular surfaces and has no obvious complications. The findings based on this *in vitro* analysis suggest that capsulorraphy, which is recommended by most authors whenever possible, and dorsal capsular prosthesis, both appear to be potentially reliable and suitable techniques.

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