FACTORS AFFECTING SUPPORT OF FULL DENTURES.

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CONTENTS.

INTRODUCTION.

Adequate retention and stability were the criteria of success for the dental prostheses of earlier times, which served mainly on aesthetic function. Many patients were content to use their dentures only when social occasion demanded, and were willing to tolerate considerable discomfort in these circumstances.

Now it is commonly expected that dentures should be of use during chewing and remain comfortable at all times, and some patients are disappointed if their artificial teeth do not confer all the advantages of a sound natural dentition. The demand for restoration of masticatory function and continous comfort requires that dentures have not only sufficient retention and stability, but also adequate support to withstand the loads imposed in the course of eating and during constant use.

In fact the majority of those who require full dentures do now find satisfaction, and relatively few suffer permanent denture disability.

Retention, the resistance of dentures to dislodgment, depends largely upon accurate impressions, models and baseplates. Materials and techniques are available to achieve this aim. If, in addition, the polished surfaces are suitably contoured to accommodate the muscles of the lips, cheeks and tongue, most retention difficulties can be overcome.

Stability of full dentures, whereby displacement by functional stresses is resisted, can be secured also in most cases by applying established principles and suitable techniques. Registration of true centric relation is facilitated by recognising varying degrees of retrusion in the horizontal component, and a suitable vertical dimension can be assessed by observing the free-way space. Occlusion of the teeth to ensure balance in lateral and protrusive movements of the mandible can be achieved by various means.

However, even when dentures have been made to accommodate to morphology and function, some patients find them intolerable because of pain and discomfort in the tissues beneath the denture bases. These are problems of the support* of the dentures, the resistance to the vertical forces arising from the occlusion of the teeth.

Retention is a basic requirement for any prosthesis, if only to ensure its continued attachment to the remaining natural tissues. Stability is necessary to ensure that the prosthesis moves in unison with the surrounding parts, and, when movement occurs, continued retention depends upon the quality of stability. Support is required when successful retention and stability allow increased function and the load factor thereby becomes significant.

The failure of a patient to tolerate full dentures may be due to inadequate retention or stability, and this demands prior attention, but pure support problems may also arise as causes of discomfort.

* The term "support" is used herein to signify resistance to the vertical loads transmitted to the tissues from the occluding surfaces of the teeth.

A review of the records of 100 consecutive patients with full denture problems, who had been seen by the author, showed that whereas 46 complained of difficulty in retention or stability, 35 complained first of discomfort in some part of the denture - bearing area. Some of the latter group would have benefitted by minor surgery or modification of prosthetic technique to correct defects which could readily be observed. Others showed no such obvious causes of discomfort.

There are indications that the loads which the tissues are required to accept in some cases may play a significant role in causing the discomfort of which these patients complain. It is this aspect of the support problem - the loads involved in the use of full dentures by individual patients - that is the main concern of this study.

The approach chosen for this study.

Clearly, the supporting tissues must be assessed to give perspective to a clinical picture of pain and discomfort leading to intolerance or inadequate function of full dentures. This was recognised as fundamental by Gibson in 1941 when he wrote:

> 'Just as anyone building a house first makes sure that the foundations are sound, so must we satisfy ourselves that those tissues which are to support dentures are in a fit and healthy condition for their reception'.

The forces exerted by the jaws are considered in relation to the loading of the supporting tissues.

The evidence of loading provided by observation of attrition of the teeth has been investigated in some detail. Since one particular type of attrition was frequently associated with complaints of intolerance of full dentures, it was pertinent to consider the load conditions under which this attrition could occur.

This presented a problem of engineering, but required a cautious approach both in the design of experiments and in the interpretation of results. Kenedi (1966) made the point by his comment that "Bio-mechanics, the study of organic bodies and their components on a macroscopic level by the application of engineering principles, is a so-called inter-or (more correctly) multi-disciplinary activity". Co-operation is required between the engineer, who contributes knowledge of materials, mechanisms, and established testing techniques, and the clinician who is aware of the variable complexity of biological structures and functions.

So experiments were made to define some of the conditions in which this distinct type of attrition could be produced. The resulting indications are given prominence in the later consideration of the diagnosis and treatment of denture intolerance due to failure of support.

II

THE SUPPORTING TISSUES.

Very highly specialised structures have evolved to support the natural dentition.

Within each tooth socket the fibrous tissue of the periodontal membrane is arranged to deal with the forces to be transmitted from the tooth to the alveolar bone. Lateral forces are opposed by fibrous strands arranged tangentially around the roots of the teeth, and occlusal forces are resisted by the oblique fibres by which each tooth is slung in its bony socket. The tissue fluid forms a hydraulic shock-absorbing system, and within the periodontal membrane is the receptor component of a complete neuro-muscular guarding system which avoids undue stress being applied by the muscles.

Compared to this highly specialised and complex mechanism, the structures used to support full dentures seem quite inadequate. The tissue which bears the load is a mucous membrane, which is adapted only to protect the underlying parts against injury and infection. In normal function no heavy pressure is placed upon this mucous membrane. In full denture prosthetics it is made to serve the same function as the fibrous tissue of the periodontal membrane which provides support for each natural tooth.

In the natural dentition, failure of the supporting tissues is frequently the limiting factor in the life of the teeth. Retention of the natural teeth, by the use of techniques, drugs and materials to restore cavities and promote resolution of infected areas, can be continued almost indefinitely. If the supporting tissues become unfit for the load, however, or the load too great for the tooth support, it is more difficult to keep the teeth healthy and useful. A similar situation obtains with artificial dentures, since the adequacy and tolerance of the tissues, or the loads which the tissues are asked to bear, frequently to decide the success or failure of a prosthesis.

The area of the supporting tissues available for a full denture, even in cases where there has been little loss of alveolar bone, is very much less than the area provided by the periodontal membranes attached to the sockets of the teeth of the natural dentition. (Watt et al., 1958).
This potential load-bearing area is further reduced as resorption of residual alveolar bone ensues.
Lammie (1956) has drawn attention to the reduction in the surface area and in the quality of the lining mucosa of the mouth which occurs in advancing years. This, he says, must affect adversely retention, stability and the comfort of the patient, because of the reduced support area and the associated atrophy and thinning of the submucosa.

Anderson (1956), discussing "The value of teeth" in his inaugural lecture to the University of St. Andrews, found the maintenance of good denture support a difficulty for persons whose natural teeth had been lost early in life because " in later years many patients suffer from constant discomfort and lack of any real chewing function due to the poor support available for dentures".

In addition to normal age changes in the supporting tissues, the effect of continued wearing of dentures must be considered as a possible factor affecting the load-bearing capacity available to the prosthetist. The reactions of the tissues beneath full dentures have been the subject of various reports in the literature.

<u>Histology of denture-bearing tissues.</u>

Wright (1929 and 1933) described hypertrophy of the mucosa, with increase of the connective tissue element and round-celled infiltration, accompanying resorption of alveolar bone. In his cases he found imbalanced occlusion and consequent unequal distribution of masticatory forces to be responsible.

Pendleton and Glupner (1935) also attributed hypertrophy of soft tissues and resorption of alveolar bone to unequal distribution of stress in their series of cases in which full upper dentures were opposed by incomplete arches of lower natural teeth. Somewhat later Pendleton (1940) published an observation that new bone formation occurred under dentures which were in well-balanced occlusion, and he offered the view that the intermittent pressure of balanced full dentures acted as a physiological stimulus and did not induce excessive alveolar resorption.

Berry and Wilkie (1964) doubt the occurrence of any beneficial adaption of alveolar bone as a result of denture-bearing. The stresses applied to the bone of the residual alveolar ridges by dentures are received as compressive forces, whereas the load is received by the alveolar bone around natural teeth as tensile forces. The tendency is for a progressive, gradual resorption of the bone of the residual alveolar ridges to occur, and gross over-loading results in an increased rate of resorption. There is no regeneration of alveolar bone which has been lost, hence excessive bone loss should be avoided by limiting where possible the load imposed by full dentures.

Various observations of the histological appearances of the soft tissues beneath dentures have been reported.

Pendleton (1951) examined edentulous areas in 126 subjects, biopsies being taken from the tuberosities the buccal and the labial surfaces of the alveolar ridges. 39 of his cases had worn dentures for periods of from 6 months to 25 years, and 87 who had no dentures were used as controls. He found that changes in the epithelium, connective tissues and bone were equally prevalent where no dentures had been worn and in denture-bearing tissues. Parakeratotic epithelium was most common, but non-cornified and hyperkeratinised areas were considered to be within the normal range. Cornified and parakeratotic appearances were seen within the same field in some instances. Fibre bundles in the connective tissue appeared in some denture-wearing specimens to be more dense, but this was possibly associated with an inflammatory rather than a mechanical cause. The residual alveolar bone showed evidence of both resorption and repair irrespective of whether it had or had not supported dentures. Low grade inflammatory reactions were seen in denture-bearing and non-denture-bearing specimens.

Ostlund (1958) studied the effect of full dentures on the soft tissues of 291 patients, 122 of whom had worn full dentures for less than 3 years and 151 for more than 3 years, the remainder, who had no dentures, being controls. Biopsies were taken from an area of the palate near to the mid-line and just anterior to the vibrating line posteriorly. He concluded that the first reaction of the tissues to a denture is a thinning of the stratum corneum and a decrease in the number of layers of cells in the stratum granulosum. There follows parakeratosis and then a complete disappearance of the keratin layer.

Marsland and Fox (1958) reported on a series of 82 cases characterised by localised pain and discomfort of the denture-bearing mucosa. These cases were treated by alveoloplasty and removal of soft tissue from painful areas. Abnormal concentrations of nerve tissue were found in areas where hypersensitivity had been experienced. Commenting on the histology of the tissues, they noted irregular thickening of the epithelium with hyperkeratinisation in some cases and parakeratosis in others. A slight degree of inflammatory infiltration was usually found.

Hedegard (1961) noted replacement of the normal horny layer by parakeratosis within three months in 8 of a group of 9 patients fitted with immediate dentures. He obtained biopsies before the removal of the teeth and again three months after extractions from the labial aspect of the alveolar ridge in the central incisor region. A normal horny layer remained in specimens from equivalent areas of the mouths of six patients for whom no immediate dentures were fitted.

Fish (1962) reported on the histological appearance of soft tissues in edentulous ridge areas, discriminating between satisfactory full denture restorations, beneath of the denture-bearing mucosa. These cases were treated by alveoloplasty and removal of soft tissue from painful areas. Abnormal concentrations of nerve tissue were found in areas where hypersensitivity had been experienced. Commenting on the histology of the tissues, they noted irregular thickening of the epithelium with hyperkeratinisation in some cases and parakeratosis in others. A slight degree of inflammatory infiltration was usually found.

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Fish (1962) reported on the histological appearance of soft tissues in edentulous ridge areas, discriminating between satisfactory full denture restorations, beneath which well keratinised epithelium was found, and cases associated with unsatisfactory dentures in which imperfect keratinisation, lymphocytosis and increased vascularisation were evident. In particular he noted that in edentulous mucosa underlying full dentures opposed by natural teeth the epithelium was denuded of keratinised cells and there was intra-epithelial leucocytosis in all the cases in this category. He concluded that in these cases "the physiological limit of the tissues" had been exceeded.

Kapur and Shklar (1963) compared biopsies of edentulous alveolar ridge mucosa in 9 subjects with corresponding areas on the opposite sides of the same mouths three months after full dentures had been fitted. They reported that the width of the stratum corneum increased after dentures had been worn - a true hyperkeratinisation - which they interpreted as a good tissue response to denture wearing for this limited period of time.

Turck (1965) described histological changes in the soft tissues of 16 partially-edentulous patients. He compared denture-bearing with non-denture-bearing tissue, and included corresponding parts of the mucosa around standing teeth in the same patients. He recognised histiotypes within the group. In most cases the epithelium showed well-defined keratinised layers which were slightly thicker in denture-bearing regions. Abnormal reactions characterised by lack of keratinisation, acanthosis and thickening of the epithelium were described and thought to be due to trauma from ill-fitting dentures. Ageing did not seem to influence the gross histological appearances.

A possible explanation of these varying reports of histological appearances under full dentures is that specimens were taken from different sites, and that there were differences in the accuracy of the denture bases and the balance of the occlusion.

Hedegard examined sections of tissue from the labial surface of the alveolar ridge,and the normal, horny layer was found to have disappeared after immediate dentures has been worn for a short time. On tissue from the crest of the alveolar ridges, Turck and Kapur and Shklar found hyperkeratinisation under dentures, as did Fish in his "satisfactory" denture cases, and Marsland and Fox in some of theirs. Ostlund reported a progressive deterioration in the keratinisation of the tissue of the posterior part of the palate. Pendleton's reports, which were based on sections from different parts of the alveolar mucosa, showed varying reactions in both denture-bearing and non-denture-bearing tissues. In the "unsatisfactory" prosthetic cases described by Fish, a less complete keratinisation was found, and in his cases of full dentures opposed by natural teeth the keratinised layer was absent.

Comparisons of denture-bearing mucosa in different areas of the same mouth were undertaken to determine whether a pattern could be discerned in the histological appearances. Sections of tissues obtained postmortem from the palate, the crest of the alveolar ridge and the lateral surface of the alveolar ridge in the first molar region are illustrated. Specimens were taken from both sides of the mouth in all cases, and the appearances on each side were found to be similar. Apparently satisfactory dentures were present, and the denture foundations appeared to be normal.

Subject to individual variations, there appears to be a pattern of more advanced keratinisation on the epithelium covering the crest of the alveolar ridge and to a lesser extent in the palate, than on the lateral aspect of the ridge. The direct load-bearing areas of the ridge and palate would seem to suffer less than the tissues of the lateral aspect of the ridge, which may, however, be subject to trauma of a frictional nature, being vulnerable to abrasion during tilting and lateral movements of the dentures upon the tissues.

In Fig. 1 - a specimen from a man aged 84 who died of myocardial infarction - a parakeratinised layer appears in all three areas, the thickness of this layer being greatest on the crest of the ridge. Compression and stratification of the surface layers of the epithelium is more marked in the section from the palate than in the epithelium from the lateral surface of the alveolar ridge. The submucosa shows no marked inflammatory change.

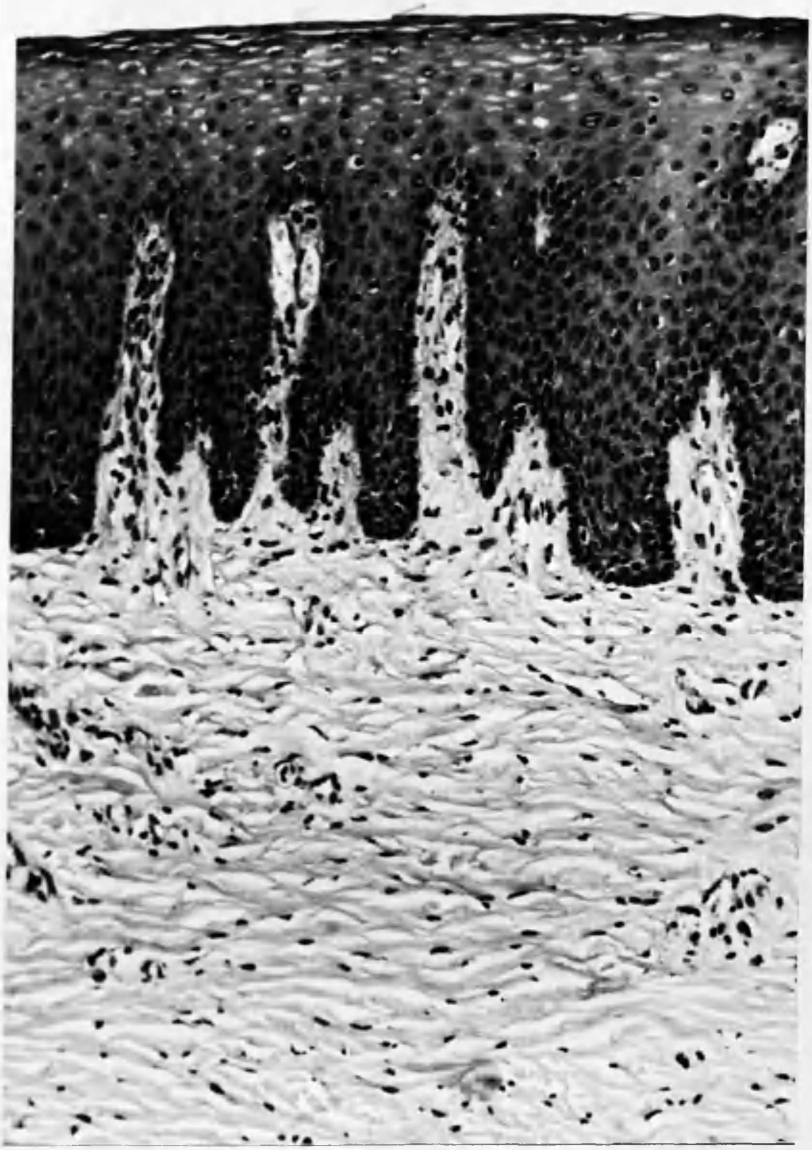
In Fig. 2 - a specimen obtained from a woman aged 74 who died of renal failure - there is again a general parakeratinisation, with some evidence of a true cornified layer on the crest of the ridge and in the palate, but not on the lateral surface of the ridge.

In Fig. 3 - a specimen from a woman aged 46 who died of carcinoma - the epithelium is more heavily parakeratotic in the sections from the palate, and tends to be minimal on the lateral surface of the alveolar ridge. There is an appearance of true keratinisation on the epithelium from the crest of the ridge. The submucosa appears to be normal.

FIGURE 1(a).

Denture-bearing mucosa.
Specimen from crest of ridge.
(x 100).

FIGURE 1(b).

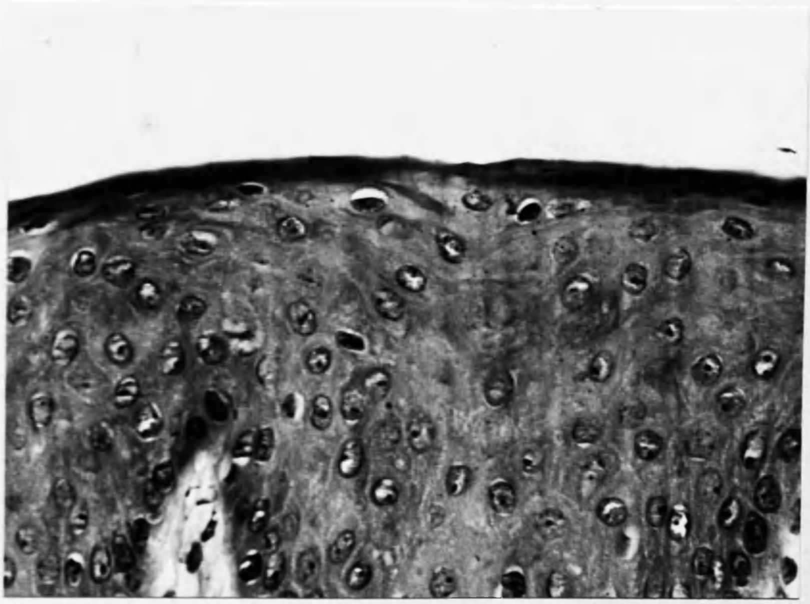


Denture-bearing mucosa.
Specimen from palate (x 100).

FIGURE 1(c).

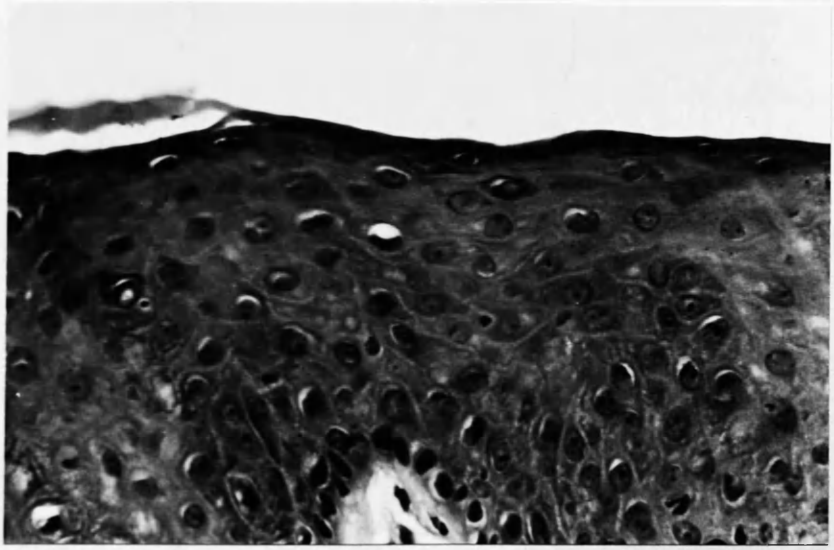
Denture-bearing mucosa.
Specimen from lateral surface of ridge.
(x 100).

FIGURE 2(a)



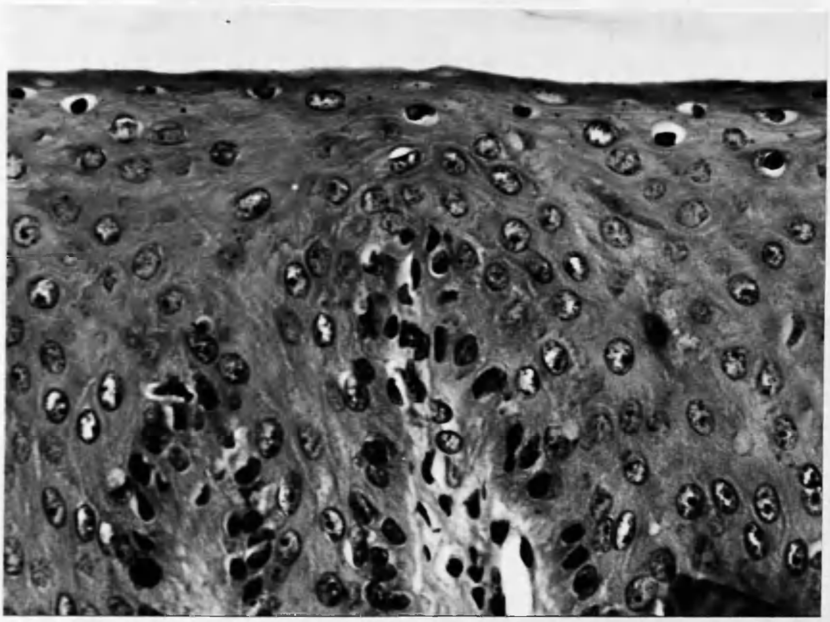
Denture-bearing mucosa.
Specimen from crest of ridge.
(x 325).

FIGURE 2(b).



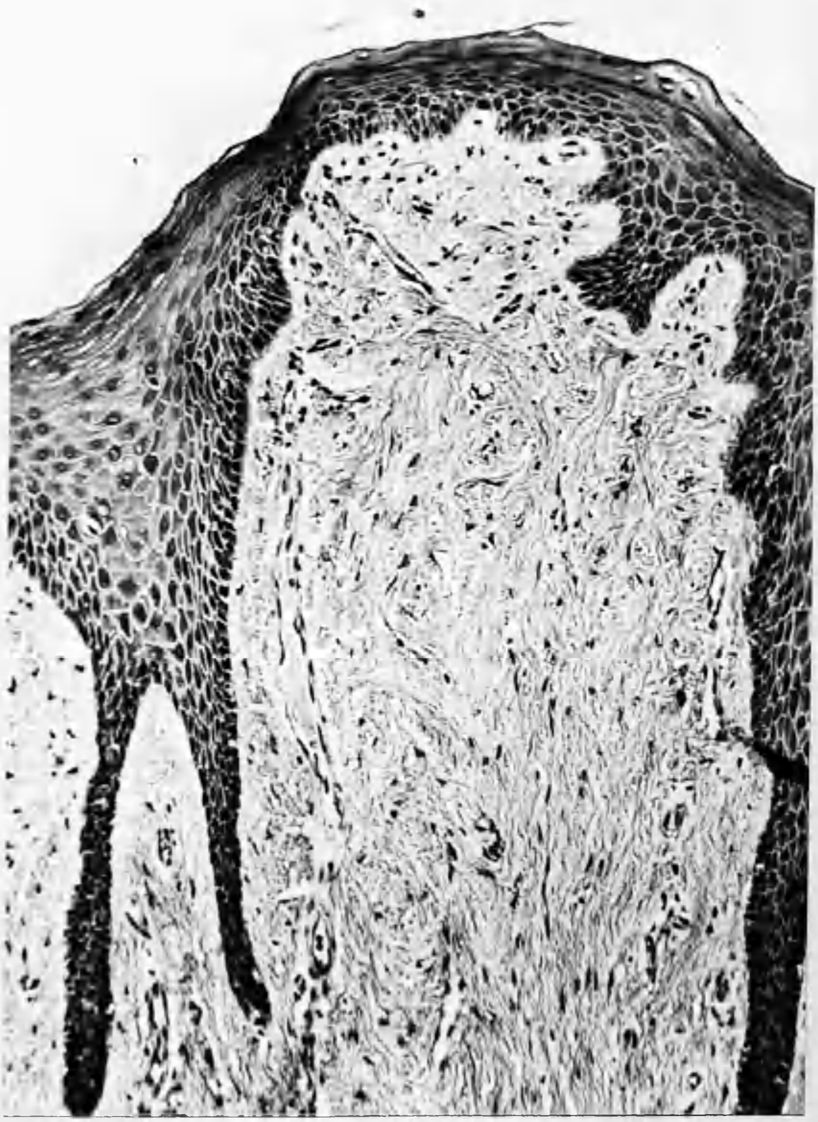
Denture-bearing mucosa.
Specimen from palate.
(x 325).

FIGURE 2(c)



Denture-bearing mucosa.
Specimen from lateral surface of ridge.
(x 325).

FIGURE 3(a).

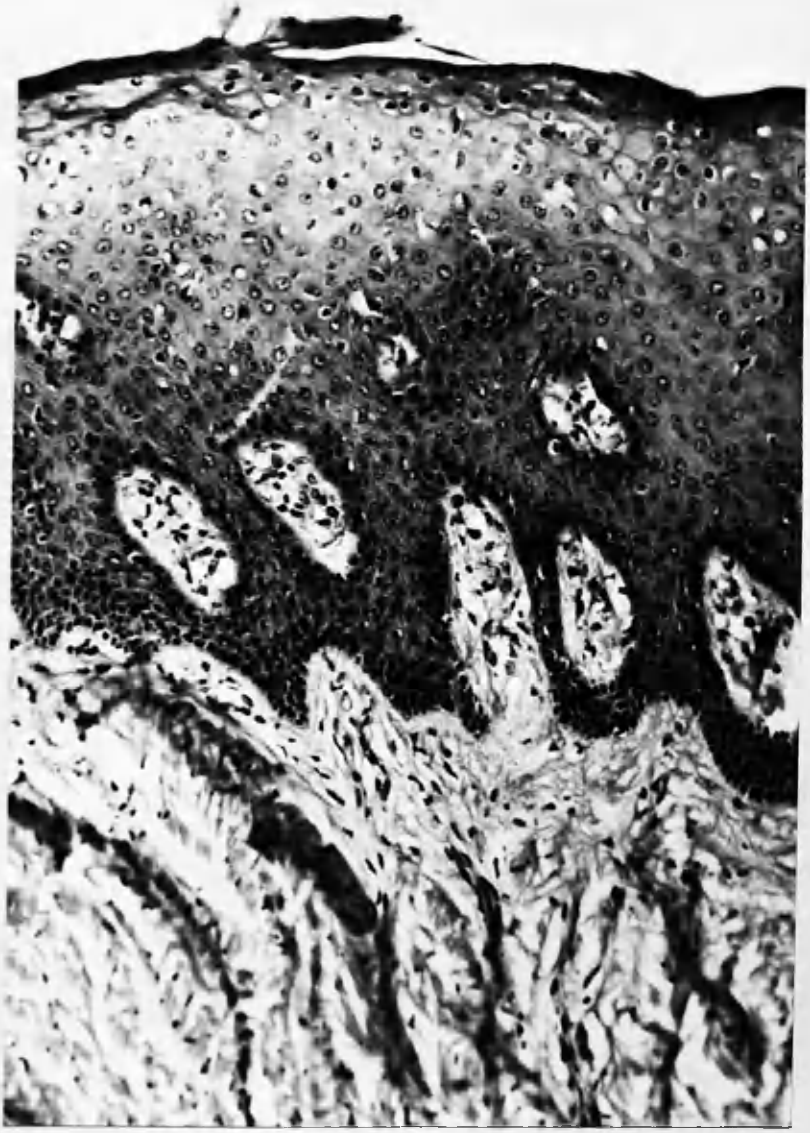


Denture-bearing mucosa.
Specimen from crest of ridge.
(x 100)

FIGURE 3(b).

Denture-bearing mucosa.
Specimen from palate.
(x 100).

FIGURE 3(c).



Denture-bearing mucosa.
Specimen from lateral surface of ridge.
(x 100).

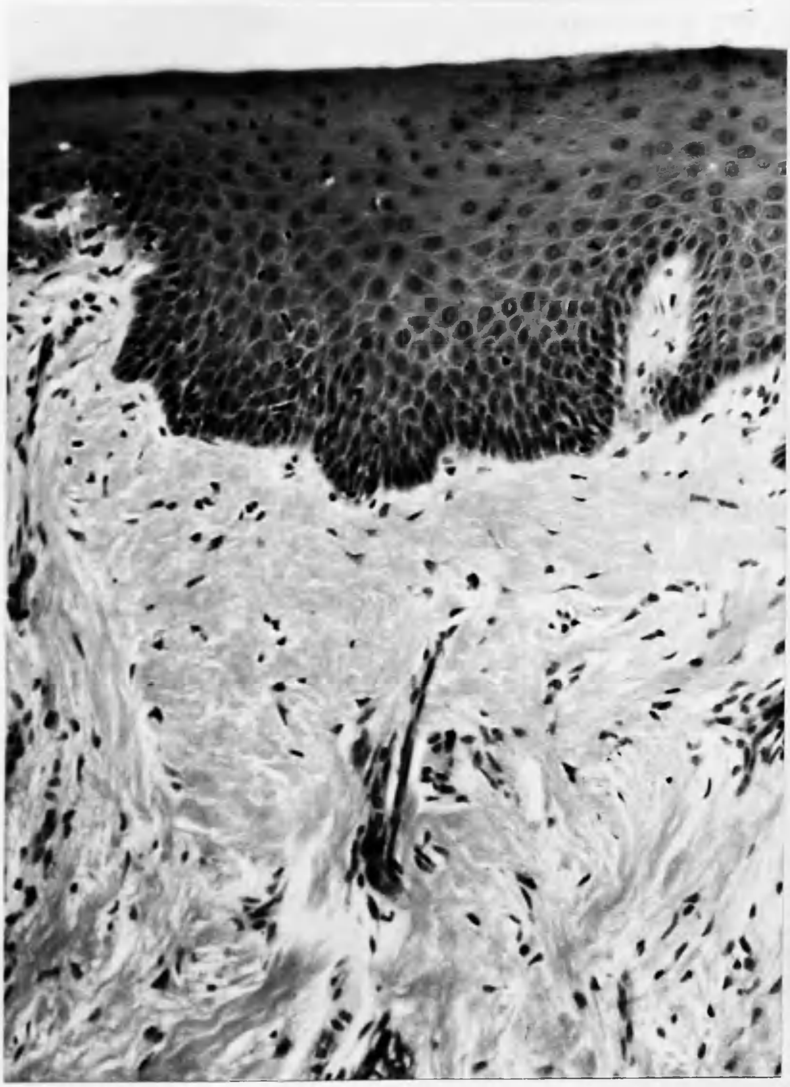
During alveoloplasty for a patient who had been wearing a gum-fitted denture for several years there was opportunity to secure a specimen of edentulous mucosa, one part of which had been beneath the denture while the other part had been uncovered. Since the artificial incisor teeth had been fitted on the centre of the crest of the residual ridge, and had become partially submerged over the years, the denture - bearing area had been subjected to considerable load, and the uncovered area was comparable in location to the adjacent area beneath the incisor teeth. (Fig. 4).

In the submucosa, there appears to be a distinct difference in the distribution of the fibrous tissue in the denture-bearing area as compared to the area which had not been subjected to load. This could be interpreted as an adaptation in response to a functional demand. No very obvious difference in the state of keratinisation of the epithelium of the loaded and unloaded tissue can be seen, however. (Fig. 5).

FIGURE 4.

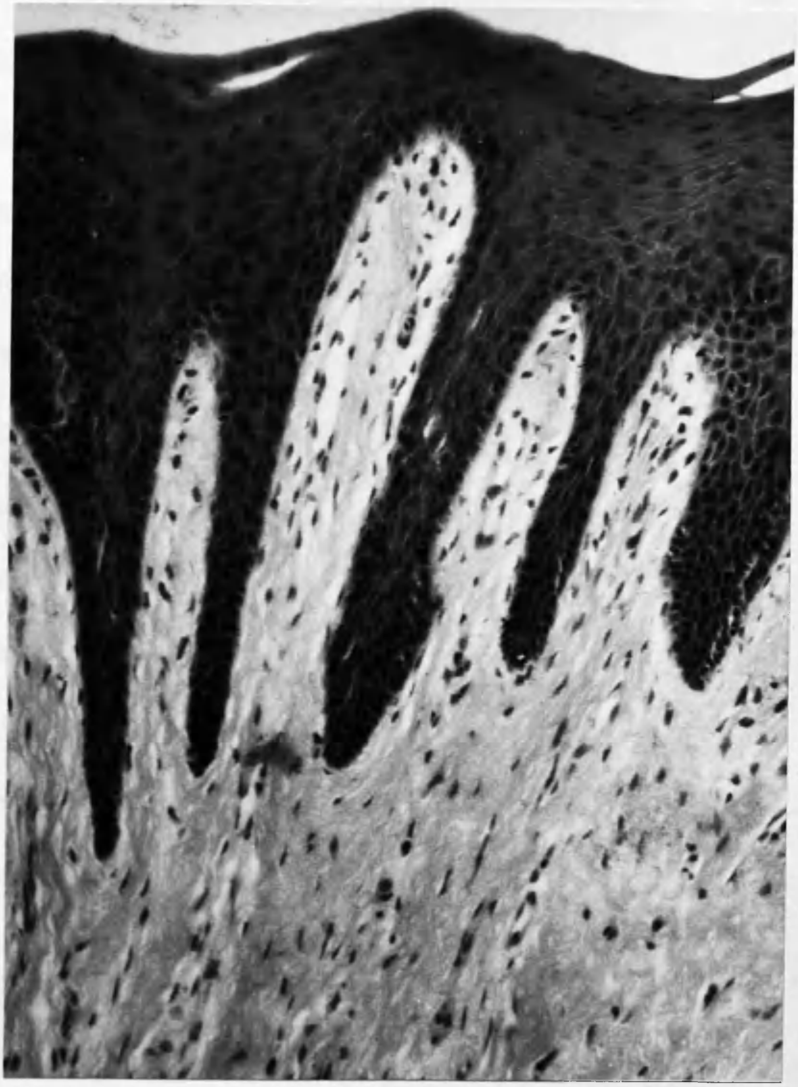
Gum-fitted denture, the incisor teeth pressing upon the mucosa.

FIGURE 5(a).



Specimen of load-bearing mucosa.
(x 130)

FIGURE 5(b).



Specimen of uncovered mucosa.
(x 130)

This accords with the findings from the literature. Some degree of instability affecting the tissues of the labial aspect of the alveolar ridge might be expected to develop in immediate dentures worn for three months. Where dentures have been worn for a long time, and where full dentures are opposed by arches of natural teeth, some instability and abrasion of the epithelium might be encountered. In the instances in which authors discerned and reported that dentures were unsatisfactory, a similar pattern of change in the histological appearances was observed. But no marked deterioration would seem to occur in the histological appearances of epithelium subjected to reasonable direct loading, as opposed to trauma caused by instability of dentures.

Clinical Signs and Symptoms.

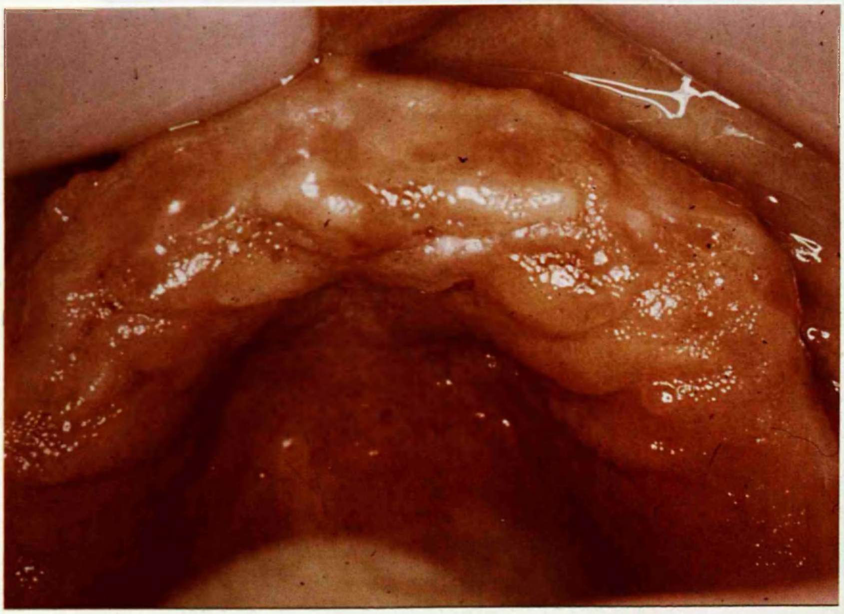
Clinical appearances are not always related to subjective symptoms of pain and discomfort.

In practice one sees acute reactions of the denture-bearing mucosa of which patients are quite unaware, since no pain or discomfort accompanies the condition. Figs. 6 and 7 illustrate an inflammatory reaction of the upper jaw of a young adult, and the neglect of hygiene of the associated denture, neither circumstance having been noticed by the patient. Fig. 8 shows acute ulceration caused by over-extension of the periphery of a new full upper denture, the injury being detected only during routine clinical examination since the patient had found no cause for complaint. The variable incidence of subjective symptoms in many patients with long-standing inflammation of the mucosa has been noted in investigations of "denture sore mouth".

The term "denture sore mouth" has been used to describe a condition of generalised chronic inflammation of the denture-bearing mucosa. Cawson (1965) suggested that the term "denture stomatitis" should be substituted, and so avoid the assumption that pain is a constant feature of the condition.

Lehner (1966) regarded denture sore mouth as synonomous with chronic atrophic candidiasis. The association of

FIGURE 6.



Inflammation of denture-bearing mucosa.

FIGURE 7.

Food stagnation on fitting surface
of denture.

FIGURE 8.

Ulceration caused by over-extended denture.

Candida albicans with the condition was noted by Cahn (1936) and Bartels (1937), and high incidences of monilia infection have been found in groups of patients examined by other workers, including Lyon and Chick (1957), Shuttleworth and Gibbs (1960), Cawson (1963) and Turrell (1966).

An investigation by MacMillan (1962) suggested that trauma caused by the tissue-fitting surface of the denture is a contributory cause, and Mack (1964) and Turrell (1966) regarded correction of prosthetic faults as a necessary part of treatment. Other aetiological factors have been suggested. The high incidence of denture sore mouth in women, especially at the age of the menopause, supported the view of Neill (1961) that hormonal imbalance may be a contributory factor. Newton (1962) suggested that a condition analagous to the sweat retention syndrone may be caused by occlusion of the orifices of the ducts of palatal glands and consequent spread of saliva into the soft tissues.

Stoy (1952) considered denture sore mouth as a condition always accompanied by symptoms. In this he found it different from "rubber-sore mouth" of the vulcanite era of which condition, he stated, the patient was frequently unaware. Pain and burning sensations in the gums, and occasionally in the tongue, he regarded as pathognomonic, while clinical signs varied with the aetiology of the condition. Retained roots, over-extension of the denture base, unrelieved hard areas, venous stasis, sepsis, primary irritation and sensitisation were causative factors found in his group of patients, whose symptoms were relieved by appropriate treatment of the apparent cause. Wearing of full dentures at night as well as by day was a constant feature which he considered contributory. It is interesting also that he quoted two cases in which symptoms returned, when the patient suffered an emotional upset, after treatment had secured relief.

Matthews (1954) described denture sore mouth as a complain of "soreness of the oral mucosa, frequently with burning sensation arising an hour or so after insertion of dentures". Among factors responsible he mentioned faulty hygiene, trauma from the denture, chemical irritants, intolerance of denture pressure and overgrowth of Monilia albicans, as well as the systemic factors of menopausal debility, acrylic allergy and oral neurosis.

So the term was used to cover many causes of pain in the tissues under dentures, but local causes such as infection and trauma received special emphasis.

Nyquist (1952) examined 1090 patients, 248 of whom were classified as having denture sore mouth which was characterised by chronic inflammatory changes, swelling and oedema. In this group few exhibited subjective symptoms, and these practically always had "traumatising dentures". 7% had burning pain in association with denture sore mouth and 4% had pain without associated clinical signs. No significant difference in the incidence of denture sore mouth was found between those who wore their dentures at night and those who did not.

Nyquist considered trauma as the most prevalent predisposing cause of denture sore mouth.

Thus, in certain adverse circumstances, an inflammatory reaction occurs in the denture-bearing mucosa. Even when clinical signs are apparent, however, the tissues may continue to provide support for the denture without discomfort.

On the other hand, discomfort and impaired function due to inadequate support may be present in the absence of any noticeable change in the appearance of the denture-bearing mucosa as well as in cases showing signs of trauma and infection. This is exemplified in the cases in which the normal morphology of the residual denture foundation is less than ideal, although the tissues themselves are quite healthy. Gross resorption of the alveolar ridges, as well as reducing the area available, also exposes to loading such unsuitable structures as the genial tubercles and the mylohyoid ridges. The absence of cortical bone on the crest of the alveolar ridges invites discomfort also, even in a normal mucosa. The thin, friable mucous membrane, often found covering a resorbed lower alveolar ridge, often lacks the cushioning effect of the firm thicker epithelium and submucosal layer derived from gingival tissues, and is less conducive to denture comfort.

Landa (1959) emphasised that the "masticatory mucosa" which occurs on the alveolar ridges and palate, is best able to withstand pressure, being attached to the periosteum. Unattached mucous membrane is less suited to support dentures with comfort. Fraleigh (1959) recognised also the importance of the denture-bearing mucosa being attached to periosteum, and he described a surgical technique for extending the area of such attached mucosa to improve the denture foundation.

When the load is borne directly upon the bone of the jaws by the use of sub-periosteal implants, the function of the dentures is improved and discomfort is reduced. Presumably the improved function is a consequence of relief from discomfort.

Lew (1953) cites a case in which increased masticatory efficiency following the insertion of an implant was thought to be responsible for such rapid wear of the occlusal surfaces of the teeth that replacement of the superstructure was required within one year. The use of metal inserts on the occlusal surfaces was thought, however, to result in excessive direct shock being transmitted to the underlying bone. Knowlton (1953) found that 4 months after inserting a lower implant a clenched load of 64 lbs. could be recorded by a subject whose average previous performance with tissue-borne dentures had been 10 lbs only. Mack (1954) includes the relief of the pressure on the mucous membrane in cases of hypersensitivity of the tissues of the denture-bearing area as one of the advantages to be derived from the use of implants. Enhanced retention obtained by the technique is a prime reason for its use, but the relief of the mucous membrane from pressure is another factor contributing to the elimination of previous denture discomfort.

It would seem, therefore, that the sensitivity of the mucous membrane to load is a limiting factor in deciding the tolerance of patients to full dentures, and the degree of function which they may be able to enjoy.

Conclusions.

The tissues on which full dentures are placed are less suitable for load-bearing than the tissues which support the natural teeth.

From the histological evidence it would appear that the normal reaction of the mucosa to denture-bearing is not unfavourable, subject to individual variations and the effects of trauma in adverse prosthetic conditions. Inflammatory reactions of the mucosa occur in certain circumstances.

Even in the presence of inflammation the mucosa may remain adequate for the function of supporting full dentures without discomfort to the patient. Some patients do suffer pain and discomfort, however, even in apparently normal denture-bearing mucosa. It is suggested that the conditions of loading are relevant in cases where pain or discomfort leads to intolerance of full dentures.

III

ASSESSING THE LOAD.

Information about the size and frequency of the forces transmitted through the teeth is relevant to many branches of dentistry. Functional forces may influence tooth position in orthodontics, occlusal trauma is a factor frequently considered in periodontology, and loading must be considered in conservative and prosthetic dentistry in relation both to the design of restorations and to the provision of adequate support for them. So it is not surprising that there have been many studies in the past of the forces generated between opposing teeth. However, the results of these investigations must be cautiously interpreted in full knowledge of the circumstances in which the data was obtained.

Biting Forces.

Interest in recording bite strength began in 1895 when Black experimented with an instrument which he called the gnathodynamometer, and various modifications of the instrument were produced during the succeeding years.

These instruments used systems of levers, springs, manometers and steel ball impressions to measure the forces when the subject exerted biting pressure upon pads attached to the arms of the instruments which were placed between the teeth.

Worner (1939), in trying to resolve differences in the biting forces recorded by various investigators, produced some interesting observations. In his own tests he employed an instrument in which pressure applied to suitably shaped biting pads was transmitted hydraulically to a small pressure gauge. He found a correlation between the force recorded and the area of the periodontal membrane of the tooth or teeth involved in the biting. He noted also that the gnathodynamometers required that the teeth be widely separated during tests by the rather bulky biting pads. Subjects, he found, improved their performance after repeated trials, and testing each day for a fortnight resulted in the forces eventually recorded being doubled. This he ascribed to the subjects becoming accustomed to the instrument and procedure, and gaining confidence. His results differed from those of Black (1895) and Klaffenback (1936) in that he recorded smaller maximum forces He ascribed this to inaccuracies of the earlier instruments in the higher ranges, the involvement of more than one tooth in each jaw due to the larger biting pads used in the earlier experiments, and possibly a decline in the biting potential of the subjects due to the reduced function over the years.

When biting force between natural teeth was compared to biting force between full dentures, a considerable reduction was found in the latter case. (Table 1).

Lim (1966) reported clenched biting forces recorded in 20 full denture wearers, finding variation between 15 lbs and 60 lbs in opposing pairs of first molar teeth, the average being 27 lbs. He found that the forces demonstrated by subjects were markedly increased when he modified his

TABLE 1.

Biting forces (in lbs.) recorded by different investigators using gnathodynamometers and providing comparisons between natural teeth and full dentures.

		Natural Dentition	Full Dentures
BLACK	Maximum	350	20 to
	Average	171	30
KLAFFENBACH	Maximum	275	53
	Average	150	22
WORNER	Maximum	195	45
	Average	110	23

experimental conditions to eliminate unilateral tilting of the dentures during tests. He noted also a slight increase in the forces recorded during the first month following insertion of dentures, and when a soft lining was used in the lower denture.

Later Lim (1967) recorded increased clenched loads, over 100 lbs. in some instances, when the forces were applied in experiments using a modification of the Bimeter described by Boos (1940). This method of applying the loads, through a central bearing device mounted between the upper and lower jaws on full baseplates, secured a more even distribution of the loads over the whole available area in each jaw than was achieved by a gnathodynamometer inserted between the teeth on one side only.

The significance of these tests of biting strength was discussed by O'Rourke (1949), and he questioned their interpretation even as evidence of muscle power. He considered that the force which the subjects applied in tests would be limited, not by the strength of their muscles, but by the capacity of their tooth supporting tissues to tolerate the load, by their sensory mechanisms, and by the discomfort, pain, or fear of pain or injury which the subjects experienced. This opinion is supported by the work of Adler (1947), who found a 30% increase in the loads recorded by subjects when he tested their bite after injecting local anaesthetic near the teeth.

Knowlton (1953) reported a dramatic increase in the clenched force produced by a patient after inserting an implant in place of a traditional denture, so removing the load from the soft tissues. The increasedmasticatory efficiency observed by Lew (1953) following fitting of an implant is an indication that during function also the force used is limited by the tolerance of the supporting tissues. The increased retention and stability afforded by an implant may be an additional factor influencing the effort which the patients were willing to expend on both clenching and chewing.

The Distribution of the Load.

In the case of natural teeth, which are independently supported, a vertical force applied to one tooth affects only the tissues supporting that tooth. In the case of a denture, however, load on one tooth must be distributed to some degree over the area covered by the baseplate. If the load is applied to one side of the arch, the tissues on the other side of the mouth may be completely relieved of pressure if the denture tends to tilt. The positive load is then concentrated upon a smaller area, thereby causing greater pressures on the mucous membrane affected.

Arstad (1959) observed the areas of blanching under transparent acrylic baseplates as evidence of the compression of the tissues under load. He considered that uneven compression of the mucosa under dentures during mastication is unavoidable. He experimented with baseplates made following the use of various impression materials - compo being excepted, but hard areas being relieved during fabrication of the baseplates - and found little difference in the pressure distribution as a result of the different impressions. The point of application of the load, and the consequent tendency of the denture to tilt, had an over-riding effect upon the area of tissues compressed.

Frechette (1955) described a method, which he had applied to one subject, which tried to measure the load experienced at selected points on the denture-bearing mucosa during mastication of various foods with dentures on which various types of artificial teeth were mounted. He used cast chrome cobalt denture bases on which circular slits provided flap-like islands or peninsulas which carried strain gauges. It was found impossible to calibrate the test dentures by applying known loads to them in the mouth and correlating the resulting strain gauge readings, apparently because of movement of the tissues and instability of the dentures. Each individual "island" was therefore calibrated extra-orally by applying air pressure within a diaphragm.

In the reduced results recorded for this subject while chewing carrots with 30° teeth, average pressures on mucosa of the buccal surface of the ridge, the crest of the ridge and the palate were 3, 25 and 12 lbs. per square inch respectively. Varying results were reported for dentures having different teeth, for different foods being chewed, and between the left and right sides of the mouth.

Stromberg (1955) was interested in measuring lateral pressures on the tissues under dentures during mastication, and he cut small windows in the buccal flanges of the dentures and mounted movable acrylic resin plungers in the window spaces. The plungers were held by flat gold spring carriers on which strain gauges were fixed, and the movements of the plungers when load was transmitted to the tissues during chewing were recorded. It was stated that the data was calibrated into "grams of pressure". Since the results were expressed in tables as "grams" only, it is not clear whether they refer to forces upon the whole area of each "window" (25 Squ.m.m.) or to pressures per unit area.

So interpretation of Stromberg's work is difficult, as is comparison with other data, but there are large differences between the recordings made on his two subjects. For instance, one subject produced averages of 37 grams on the working side and 86 grams on the balancing side while eating peanuts, while the corresponding averages for the other subject were 15.6 grams and 15 grams. Wide variations of this order appear in the data obtained when different foods were chewed and when zero-cusp teeth were used.

Lawson (1960) evaluated the methods used by Frechette and Stromberg, devising an experiment to simulate the circumstances in which the load on a selected part of the soft tissue was measured. He found that whenever the flap or plunger moved, as it must move to permit recordings on strain gauges, a portion of the load which should have been accepted by the moving part was transferred to the surrounding baseplate, thus invalidating any reading obtained.

He deduced also that unpredictable variation in tissue thickness would require to be compensated to allow proper calibration of the gauge strains in terms of pressure upon the tissue.

Wain (1964) used a capacitance transducer, monitoring the movement of a small diaphragm inserted into a denture during chewing, swallowing and clenching. When the transducer was located in the buccal flange and postero-laterally in the palate, similar readings were recorded during chewing, swallowing, and when a maximum bite was applied. It was emphasised that the same pressures occurring during swallowing could be recorded at various sites in the oral cavity when the diaphragm was not in contact with mucosa. No recordings of pressures on the crest of the alveolar ridge were quoted.

It would appear that Wain's measurements referred to fluid pressures in a film of saliva between the sensing diaphragm and the mucosa, and to air pressure changes in the oral cavity.

Lawson (1960) suggested that to obtain valid recordings of the actual forces per unit area on the denture-bearing mucosa requires a system by which displacement of any plunger or diaphragm used as a sensing device in contact with the tissues could be corrected before each reading is accepted. No such method for measuring pressures upon different parts of the denture-bearing mucosa, either under clenched loads or during mastication, appears to have been reported, and so reliable direct measurements of such pressures are not available.

Because of the many varying factors which must influence the distribution of the forces transmitted from the occlusal surfaces of the teeth to the denture supporting tissues - individual jaw movement patterns, balance of occlusion, relation of teeth to alveolar ridges and thickness and resilience of the soft tissues - it is not possible to deduce how much of the total load may fall to be supported by any given areas. Whatever the distribution may be, however, its effect upon the tissues will be related to the total denture-bearing area available in each case.

Denture-bearing Area.

The areas available for the support of the loads applied through full denture bases have been estimated in both the upper and lower jaws of 20 edentulous patients selected at random. In considering vertical loading it is appropriate to use a vertical projection of the denture base to calculate the area of distribution.

Wax baseplates extending to the normal limits of full upper and full lower dentures were made on master models for each case. These were removed from the models and placed on graph paper, on which projections of the peripheral limits were traced. (Fig. 9). The area within each outline was then computed, yielding the results shown in Table II .

FIGURE 9.

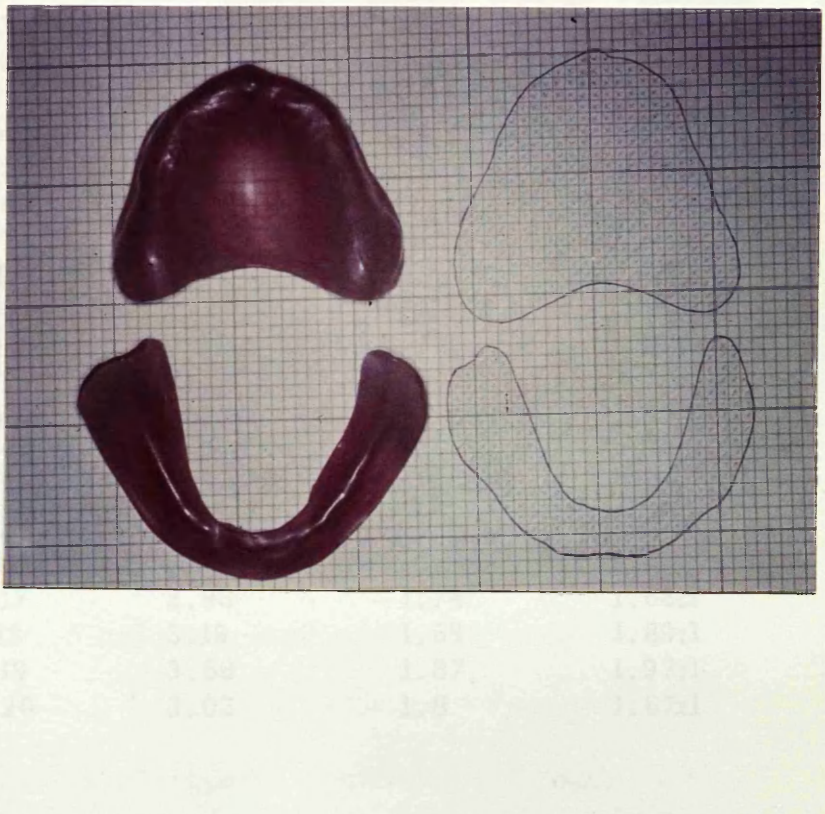


Illustration of the method used
to ascertain denture-bearing areas.

TABLE III.

Estimations of Denture-bearing Areas.

Case No.	Upper (Squ.in.)	Lower (Squ.in.)	Ratio U/L
1	3.04	1.61	1.89:1
2	4.08	2.07	1.97:1
3	3.00	2.02	1.48:1
4	3.66	1.99	1.84:1
5	3.35	1.78	1.88:1
6	4.25	2.06	2.06:1
7	2.82	1.87	1.51:1
8	3.25	1.78	1.82:1
9	4.82	2.26	2.13:1
10	3 .51	1.82	1.93:1
11	3.65	2.11	1.78:1
12	3.36	1.74	1.93:1
13	3.34	1.86	1.79:1
14	3.76	1.85	2.03:1
15	4.48	2.10	2.13:1
16	3.93	1.94	2.03:1
17	2.93	1.74	1.68:1
18	3.19	1.69	1.89:1
19	3.68	1.87	1.97:1
20	3.02	1.8	1.67:1

The variation in area is considerable - the largest being almost twice the smallest in the upper jaws, and almost one and one half times greater than the smallest among the lower jaws. The mean denture-bearing areas in this sample were 3.56 squ. in. in the upper and 1.90 squ. in. in the lower.

The corresponding areas of support available for a complete natural dentition, as obtained by adding the areas of the periodontal membranes of the teeth which were quoted by Watt et al. (1958), are 7.10 squ. in. for the upper jaw - twice the average full upper denture-bearing area - and 6.92 squ. in. for the lower jaw - more than 3½ times the average full lower denture-bearing area. The load-bearing area of the sole of a foot in one selected subject offers another interesting comparison. It was found to be in the region of 10 squ. in., and adapted to bear a load of approximately 160 lbs. This, considered in conjunction with the fact that the mucosa of the edentulous mouth is not adapted to bearing load, is sufficient explanation of the failure of denture-wearing subjects to demonstrate heavy biting forces.

The ratio of upper to lower vertical load-bearing areas shows a diversity also, varying from 2.13 : 1 to 1.48 : 1, with an average ratio of 1.87 :1 within the group examined.

When the total load applied through the teeth is considered in relation to the total denture-bearing area, a more useful assessment of the support which the tissues are required to provide can be made. Although it is not valid to assume an equal distribution of the load and so recognise an average pressure per unit area, it is clear that the large differences in vertical load-bearing areas between individuals, and between the upper and the lower full denture foundations, must be reflected in the tolerance to any given load.

Functional Forces.

Experiments with gnathodynamometers provide information about situations in which maximum static forces are produced between the teeth for short periods of time, and their relevance to conditions of normal function is mainly that they demonstrate the limiting factor of the tolerance of the supporting tissues.

The opinion that the forces exerted in tests of biting power were greater than those required for chewing was tested by Black, who described a dinner party, attended by distinguished observers, at which he submitted samples of the food to experimental crushing in an instrument which he called a phagodynamometer. The food was placed between two opposing molar teeth which crushed the specimens as in a vice while the force applied was measured. The absence of lateral shearing or grinding action probably caused his results to show much greater forces than those obtained in experiments on subjects actually chewing food, as was shown by Head (1906), but they were much less than the clenched biting forces which he had measured.

To assess the loading of the tissues during normal jaw function is difficult, but it is the functional loads which have a more direct bearing on physiological and clinical problems. Progress in electronics has stimulated efforts in this field in recent years, but interpretation of the results must take account of the extent to which the experimental methods simulate conditions of normal function for the subjects.

Howell and Manly (1948) used an electronic measuring device to produce an elegant gnathodynamometer to measure clenched loads, and this apparatus was extended and adapted by Howell and Brudevold (1950) so that a transducer could be placed beneath the teeth on one side of a denture to record loads while food was being chewed. Deflection of a flat spring by the load caused a change in its separation from a coil, and this caused a variation in the induction of the coil, which was recorded on a micro-ammeter.

Tests were made while the subject chewed peanuts, shredded coconut, and raisins, to represent both brittle and tougher goods.
The maximum force of 7.2 kg. (15.8 lb.) recorded on a molar tooth while chewing raisins, was much higher than the average forces recorded on single teeth, which varied from 0.4 to 2.8 kg. (0.9 to 6.1 lb.).

In 1953 Yurkstas and Curby repeated Howell and Brudevold's studies on dentures with some modifications to the technique to obtain greater stability of results, using four subjects and a variety of foods. The maximum load recorded in this investigation was 12 kg. (26.4 lb.) but average loads per tooth were again much lower, being between 0.3 and 1.8 kg. (0.7 and 4 lbs.).

Anderson (1953 and 1956) made measurements of the load upon a gold inlay in a natural molar tooth by incorporating a strain gauge in the inlay. Deflection of the steel plate to which the strain gauge was attached produced changes in the electrical conductivity of the resistance wire in the gauge. So, by passing a small current through the strain gauge by means of fine wires led out of the mouth to suitable recording apparatus, deflection of the steel plate caused by force transmitted from the opposing tooth could be measured in terms of current variations. By calibrating the deflection of the steel plate in terms of the stress required to produce the varying degrees of deflection, a record of stress per unit area was obtained. Later in 1956, Anderson re-calibrated the apparatus so that his results could be expressed as a load per tooth. A maximum load of 15 kg. (33 lbs.) on the whole tooth was recorded.

Four subjects were observed while chewing biscuits, carrot, and cooked meat. Loads applied tended to increase towards the end of every chewing sequence, as the food particles became smaller, and reached a peak at jaw closure during swallowing. The maximum loads recorded while chewing meat were less than those occurring with biscuits and carrot.

Comparison of these observations confirms that functional loading during mastication, as well as maximum biting forces, is less in denture wearers than in those using natural teeth.

A common feature of the apparatus used in these experiments, designed to measure the forces borne by the teeth during normal function, is that wire leads pass from the measuring instruments inside the subject's mouth to the recording apparatus. This circumstance imposes the artificial environment of the laboratory, which is a disadvantage in studies of functions which may be modified by subjective influences. Mastication is such a function. Eating habits are very subject to social influences, and close observation of a person chewing may lead to embarrassment and the adoption of unnatural mannerisms. The adjacent electronic recording appratus is necessarily rather obtrusive and may modify the subject's normal behaviour, and the physical inconvenience of wire passing between the lips is at least a constant reminder that the whole act is under scrutiny.

In addition to this risk of the laboratory conditions changing the behaviour patterns, these experiments are limited in the time factor. The effects of loading on teeth are not a result only of the amount of force applied on each chewing thrust, but involve also the frequency and the time during which loads are applied. Laboratory experiments, such as those described, record only small samples of the total function. They ignore also possible habitual para-functional activities which may play an important role in the loading of teeth in many cases.

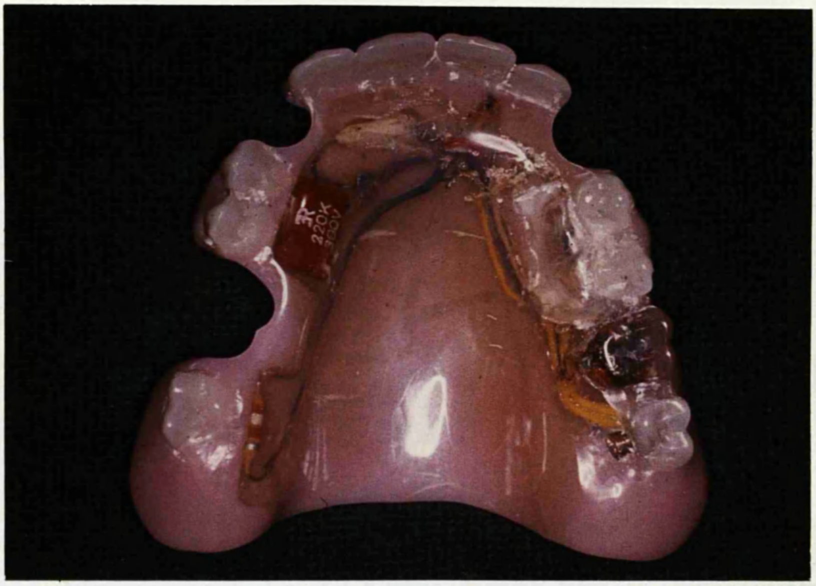
The significance of loading at times other than during mastication of food was well demonstrated by Brewer (1963) who recorded tooth contacts during sleep totalling $2\frac{1}{2}$ hours in the course of one night in one individual. The forces accompanying these para-functional contacts were not recorded, however.

The system used by Brewer was radio telemetry, a method now frequently applied in biological research, of which the best known example is the radio pill used to investigate chemical and peristaltic changes in the digestive system. The transducer and transmitter make use of miniature electronic components which can be arranged within a denture or a bridge, and the subject need not be inconvenienced by their presence. The power source - usually a small mercury cell such as is used in hearing aids - is the bulkiest of the components and must be accessible for replacement when exhausted. No wires pass from the mouth so this part of the system is discreet and unobtrusive.

Figs. 10 and 11 illustrate a transmitter incorporated in an acrylic partial denture, and the size of the components. Experiments in telemetry using such a system have provided experience through which the potential of the method has been assessed.

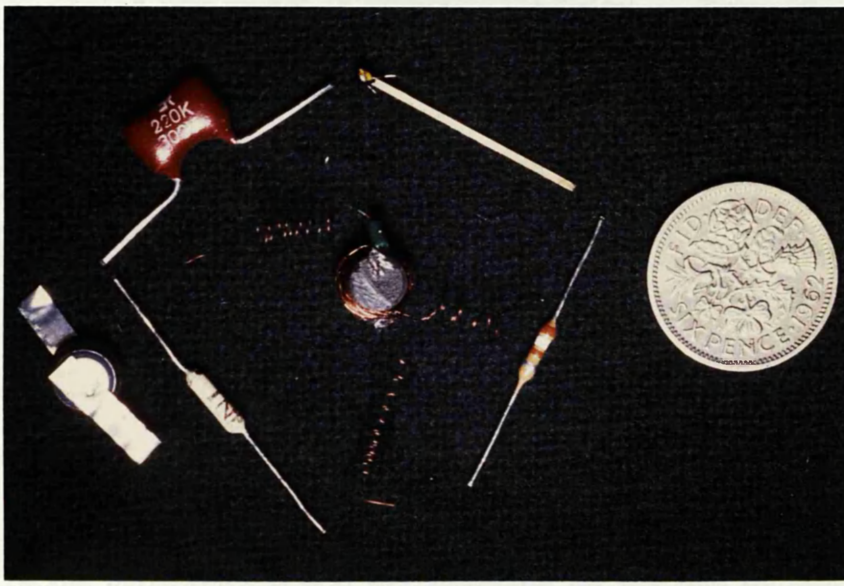
The receiving aerial may be a wire loop worn under the collar with a lead to the receiver

FIGURE 10.



A simple partial denture incorporating a radio transmitter, which has been used to study the value and limitations of telemetry.

FIGURE 11.



The components of the transmitter
with an indication of scale.

and recorder, which restricts the subject to some extent , or the signal may be re-transmitted, by a more powerful, but small, transmitter carried on the person, to a more distant location where the signal is again received and recorded. The recording equipment is necessarily bulky. The intrusion of radio interference presents a difficulty in systems where the signal is weak, and demands screening of the subject with consequent restriction of his freedom during the periods of observation.

The avoidance of artifical laboratory conditions which might inhibit the natural behaviour of the subject, or interfere with his normal way of life, is the main reason and justification for the use of telemetry in this context. However, at the present stage of technical development, radio telemetry fails to record a complete picture of all the functional and para-functional activity of a subject over long periods.

It is felt that the forces involved in para-functional tooth contacts - "empty movements" which include clenching and grinding of the teeth - must be considered as a part of the loading which the tissues are required to support, and their significance must be assessed.

A time factor is involved also. All the methods previously used to record loads upon teeth have failed to provide information about the duration and frequency of application of the forces under conditions of normal behaviour for the subject, which must produce a cumulative effect upon the tooth supporting tissues in each individual.

It is interesting to observe and to try to interpret attrition occurring on teeth. Attrition is a result of work done by the teeth, and reflects the stresses experienced by the supporting tissues. So it is an indication of the functional history of the teeth and their supporting tissues, and it may provide an accumulated record of the effect of all the loading of the teeth of an individual.

It takes account, not only of the effects of masticatory load, but also of the effects of non-functional loading such as is caused by habits of clenching and grinding the teeth.

This suggests an alternative method of assessing the load transmitted through the teeth to the tissues which support them, especially in cases where excessive loading is suspected.

IV

ATTRITION OF TEETH.

Attrition occurring on artificial teeth is a useful sign in cases involving failure of the support of full dentures. It can be observed on clinical examination, and the age of the dentures denotes the time during which it occurred. This presents a possibility of assessing the load experience of the teeth and the supporting tissues, if the conditions in which attrition is produced can be defined.

Attrition of teeth, if loss of tooth substance usually classified as abrasion and erosion is excluded, is due to mechanical wear either between opposing teeth or between teeth and food matter. Stones (1962) stated that "attrition denotes a mechanical wearing down of the surfaces of the teeth as a result of the mastication of food", and seems to exclude the effects of tooth-to-tooth contacts which are not part of the chewing process. Weinberger (1955) claimed that attrition is due to bruxism, and Galloway (1956) thought it is caused also during swallowing rather than during mastication.

It seems reasonable to include within the meaning of the term attrition all circumstances in which function or parafunction causes tooth wear, but it is still important to consider whether the intervention of food between the teeth contributes to the wearing process or whether actual contact or opposing teeth is responsible.

In the comparative field examples of both processes can be found. Food seems to play a major role in attrition in the herbivorous species, more obviously where lower incisors which have no opponents in the upper jaw show marked attrition.

Hitchin (1948) used observations of attrition patterns in sheep as evidence of conditions of loading of the teeth which in some instances led to failure of the tooth supporting structures. However, grasses are exceptionally abrasive foods since they contain siliceous inclusions not found even in other vegetable matter (Baker et al., 1959).

In the carnivora, the sites of attrition suggest that the process responsible is sliding contact between tooth surfaces occurring during shearing of flesh, the toughness of the food demanding vigorous action to achieve comminution. In the former case, therefore, the abrasive nature of the food caused direct wear of the teeth, and in the latter the tough character of the food required muscular effort resulting in forceful tooth-to-tooth contact.

Discussing Australian aborigines, Campbell (1939) thought that both factors operate, ascribing their marked attrition to "vigorous chewing habits entailing forceful apposition and rubbing together of tooth surfaces and the presence of food and incorporated foreign material which has an abrasive effect on tooth substance."

Since the diet of modern man includes very few foods of an abrasive nature, attrition would seem to be mainly due to forceful tooth contact in his case, and, since strenous chewing is seldom required, these forceful tooth contacts may occur at times other than during mastication.

Clinical Survey.

In the course of an investigation by the author concerning the amount of wear occurring in acrylic artificial teeth during normal use in the mouth, varying and distinct types of wear were observed (Thomson, 1963). Although the original object of the observations was to learn the extent to which wear of acrylic teeth might cause early loss of suitable occlusion and imbalance of dentures, the different patterns of the attrition attracted more interest, and to try to explain these differences information about the patients' habits which might have a bearing on the wear of the teeth was obtained and recorded. (Table III).

The persons examined were patients for whom complete dentures had been made in the Prosthetic Department of the Glasgow Dental Hospital four years previously. Letters of recall attracted a 70% response, and a number were returned because addresses had altered and were untraced.

SOME INFORMATION OBTAINED DURING A SURVEY OF 80 PATIENTS FOR WHOM FULL DENTURES HAD BEEN MADE FOUR YEARS PREVIOUSLY.

QUESTIONS.	ANSWERS.		
	Always	Sometimes	No
Do your dentures give satisfaction?	64	11	5
Do you use them every day?	70	6	4
Do you wear them at night?	38	5	37
Do you use them when eating?	66	9	5

	Insignificant	Moderate	Severe
Assessment of tooth wear.	40	22	18

Diets including salads twice weekly.	17
Aware of grinding or clenching teeth	16

Preferred method of cleansing dentures:	Soap and water	22
	Immersion cleanser	23
	Toothpaste	25
	Domestic Bleach	5
	Unidentified	5

TABLE III.

The examination was begun by enquiring in general terms about the patients' satisfaction with the dentures. 80% expressed unqualified satisfaction. More searching questions followed, concerning the actual use made of the dentures - were they worn continuously, were they worn at night, were they used during meals? This revealed a small number of persons who were content to use their dentures only for social appearances, which seemed in most cases to reflect a preconceived expectation of limited function rather than any prosthetic failure. Diet was discussed with particular reference to the consistency of the foods preferred and the usual consumption of salads and sweets. The method used to clean the dentures was noted, and habits of clenching or grinding the teeth were made a subject of special enquiry. After taking a history on these lines, the retention and stability of the dentures was checked and the condition of the mouth and the dentures was recorded.

The outstanding features which this planned review of former patients revealed have since been observed many times in other patients who attend for examination prior to the provision of new dentures, and also in many of those who are referred to hospital because of special denture difficulties.

Patterns of Wear.

Three distinct types of wear of acrylic teeth were observed, and by relating these to the case histories it was possible to distinguish the causes of the different patterns of wear. Of course, more than one cause may be involved, and combinations of different wear patterns were found. Many acrylic dentures showed very little tooth wear even after four years of use.

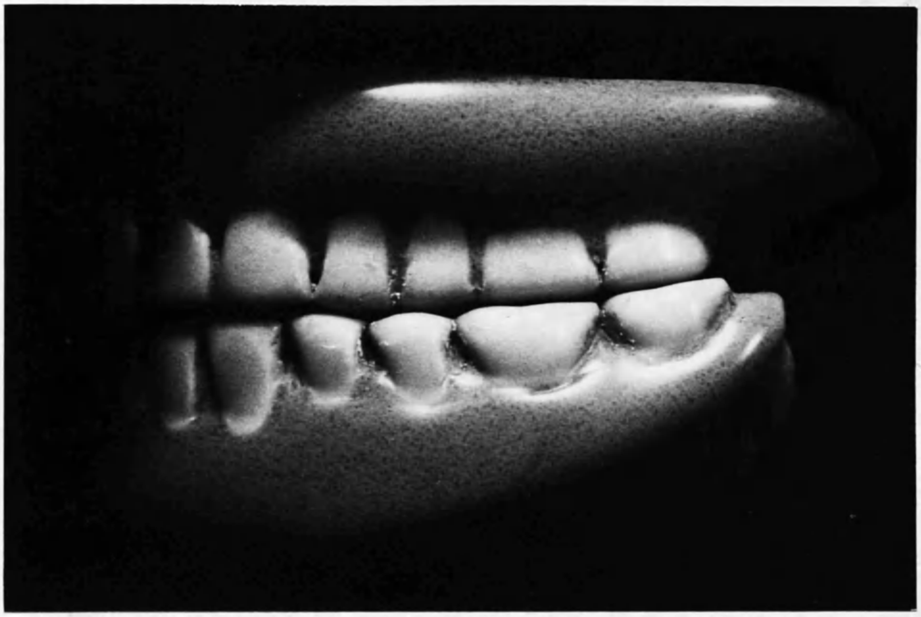
TYPE 1

Wear of acrylic dentures caused by injudicious cleansing methods must first be identified so that it can be excluded from consideration of the effects of function in the mouth. Extreme cases of dentures ruined by enthusiastic use of abrasive materials for denture cleaning are sometimes seen.

Undue concern about hygiene, an attempt to "whiten" the teeth, or the use of household cleansers intended for other purposes, are the usual causes of the damage. But lesser degrees of wear due to cleaning with abrasive agents, including some proprietary denture cleansers, are seen, and can be distinguished by the overall reduction of the more prominent parts of the dentures, both teeth and acrylic base, which are readily accessible and more vulnerable. Surface contours are gradually obliterated on all parts of the denture. (Fig. 12.).

Wear of acrylic teeth occurring during use in the mouth is usually confined to the occluding tooth surfaces, although instances of wear of the buccal surfaces of posterior teeth and the adjacent buccal flanges, caused by sucking boiled sweets and lozenges while they are held between the cheeks and the dentures, have been seen. These instances are not relevant to the present discussion except insofar as they demonstrate the potential abrasive action of sweets on acrylic resin.

FIGURE 12.



Dentures showing wear of acrylic caused
by continued use of an abrasive cleanser.

Attrition of the occluding surfaces of acrylic teeth can be caused by friction of food on the acrylic, or by actual contact of tooth against tooth. The two types can be distinguished and so the predominant cause can be identified.

TYPE 2.

When friction of food causes attrition of acrylic teeth there is a reduction in cusp height which eventually progresses to an irregular obliteration of the occlusal contours. (Figs.13 and14). The surface polish deteriorates so that staining occurs, and quite rough surfaces with inadequate occlusion may result. This wear by food is most often seen in persons who frequently eat salads containing uncooked vegetables - lettuce, carrots, etc. - which require positive and vigorous chewing. In the course of these investigations, it was noticeable that comparatively few of the patients ate salads even once a week in season. The reason for this did not appear to be masticatory disability

FIGURE 13.

Acrylic teeth worn by friction of food.

FIGURE 14.

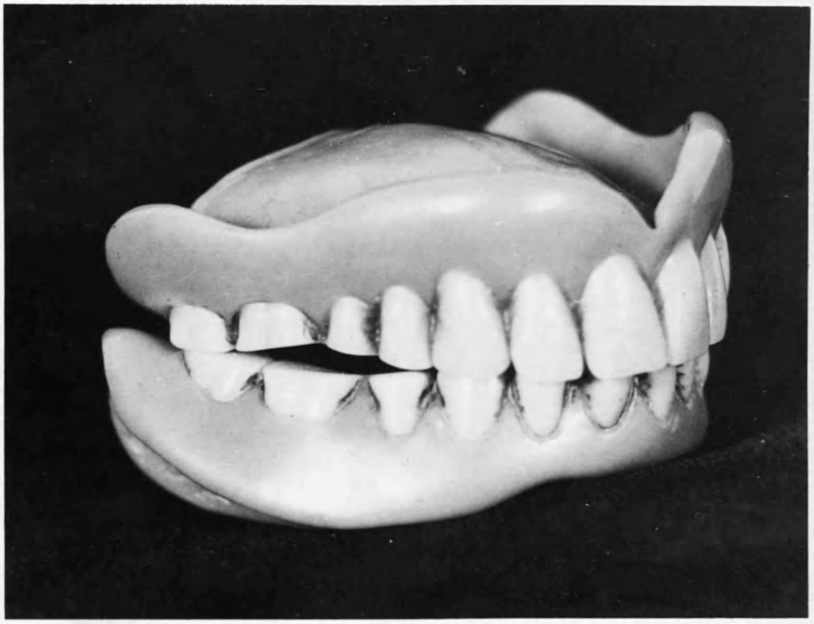
Wear of acrylic teeth caused by food-rough surfaces and loss of occlusal detail - a vegetarian diet in this case.

consequent upon the use of full dentures, but rather a habit or preference of the patients not to include salads in their usual diet. Hard sweets and nuts, when eaten regularly, produced gross attrition of acrylic tooth surfaces. In particular, boiled sweets, (which were said to be consumed by "sucking" but which clearly were held between the teeth), caused so much wear that occlusal contact was entirely lost in the habitually preferred parts of the dentures (Figs. 15 and 16). Apart from the items mentioned, however, it seems that acrylic teeth resist severe attrition due to friction by most of the foods in the usual diet of the patients examined, and wear from this cause was usually not significant in dentures up to five years old.

TYPE.3.

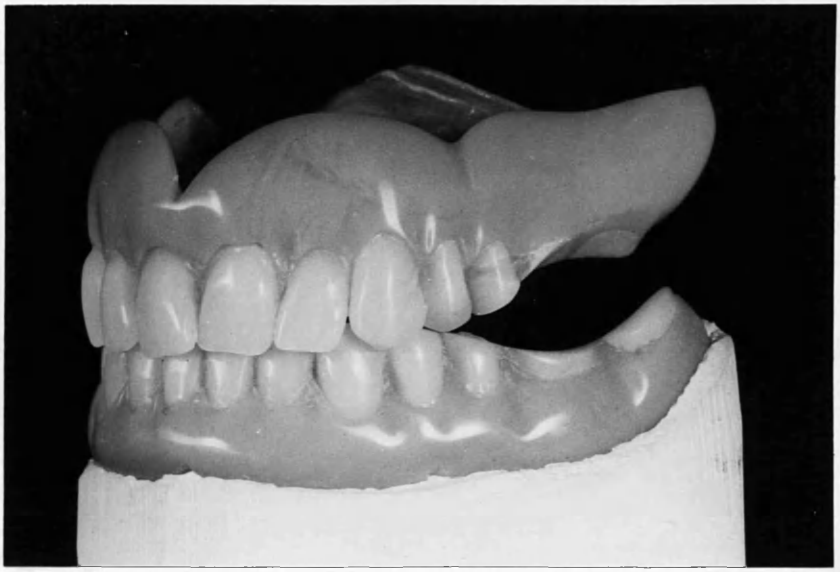
A third distinct type of wear of acrylic teeth was observed. This was of special interest, and is in itself significant as an indication of habits of the patient which might escape consideration if the pattern of attrition was not recognised.

FIGURE 15.



Typical wear of acrylic teeth caused in course of consuming boiled sweets.

FIGURE 16.



Extreme degree of acrylic tooth wear, caused in 14 months of use by a patient who consumed at least 2 lbs. of lozenges per week.

This type of attrition varies in degree, as do the other types, but, whether it is confined to small facets on occluding cusps or is so extensive as to cause flattening of the whole occlusal and incisal surfaces of the teeth, the areas affected remain highly polished and in close contact when the upper and lower teeth are suitably occluded. This is in contrast to the rough surfaces and loss of close occlusion which characterises attrition of acrylic teeth caused by food. In these cases the dentures appear to be accurately ground into perfect occlusion between flat contacting areas which are well defined, and one can visualise that no food particles could have been interposed between the teeth when the wear occurred. (Figs 17, 18, 19 and 20).

In 20% of the group of patients recalled after they had worn all-acrylic dentures for four years, attrition of this type was found. In all these instances it was possible to obtain reports of one common factor, namely a habit of clenching or grinding the teeth together. Associated with these signs and histories, in most cases,

FIGURE 17.

Wear on acrylic teeth occurring in the case of a patient who practised habitual tooth grinding.

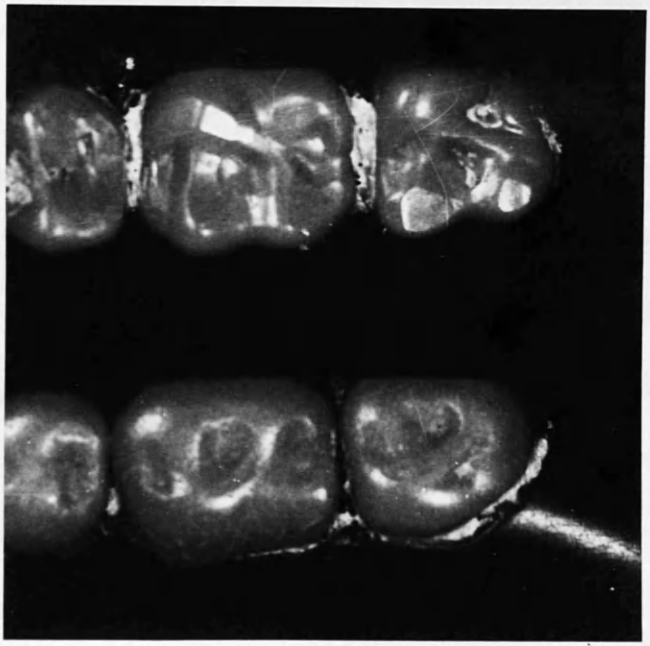
FIGURE 18.

Acrylic teeth of dentures accurately ground into sliding occlusion by a habit of persistent and vigorous tooth-grinding.

FIGURE 19.

Polished facets worn on acrylic teeth by a persistent clenching and grinding habit.

FIGURE 20.



Comparison of distinct patterns of wear of acrylic teeth due to a habitual clenching of the teeth (above), and use of toothpaste for cleaning the dentures (below).

were symptoms such as discomfort in the denture-bearing areas, which might indicate over-loading. It seemed clear that a causal relationship existed between the habit of clenching or grinding the teeth and the typical attrition seen on the acrylic.

Comment.

Franks (1962) classified wear on acrylic teeth, in a review of 140 patients who had worn dentures for 4 - 5 years, as slight, moderate and severe. These degrees of wear were related by him to the types of masticatory function demonstrated by the subjects, the examiner's assessment of the success of the prosthetic technique, and the incidence of fracture of dentures. Loss of occlusion of posterior teeth in centric relation, and the adoption of protrusive positions of the mandible in order to achieve satisfactory occlusion of the teeth, were noted in 37 cases as an unfortunate consequence of moderate and severe wear of acrylic teeth. On the basis that there appeared to be no correlation between tooth wear and the daily period during which the dentures were worn, it was suggested that tooth wear was due to food abrasion and not to contact between opposing teeth.

On the basis of the present observations, it would certainly be agreed that tooth wear due to tooth-to-tooth contact does not cause loss of occlusion of the posterior teeth. Rather does it promote a more intimate and extensive area of contact by a process of milling of the opposing surfaces. But to the food factor there must be added the wear due to injudicious use of abrasive cleansers, as a cause of loss of occlusion. No data on diet, method of cleansing or evidence of non-functional occluding habits were recorded by Franks, nor were any different patterns of wear of acrylic teeth described. It must be assumed, therefore, that a proportion of the acrylic tooth wear which he observed should be ascribed to the action of abrasive cleansers, and that a proportion of the 53 cases of slight wear and the 22 cases of moderate and severe wear, which he found to have some contact of posterior teeth in centric relation, may have exhibited a wear pattern indicative of non-functional clenching and grinding habits.

The 20% of the patients reviewed by the author in whom visual evidence of facetting due to clenching and grinding was seen is probably a low estimate of the prevalence of the habit within the group. The facets are difficult to discern in many cases, identification depending upon light reflection from highly polished areas being observed. In cases in which the patient indulges in clenching or clamping of the teeth as opposed to more active gnashing, the areas of wear may be small - although the force used is not necessarily less. It is probable also that in cases in which the patient used abrasive cleansers enthusiastically, evidence of tooth-to-tooth contacts would be obliterated.

The finding in so many instances of evidence of a habit of clenching or grinding of the teeth in denture-wearers implies some increase in the time during which positive load is imposed upon the denture foundation, in addition to the purely functional loading involved in the mastication of food and in tooth contact during swallowing. It was not known however, whether significant loading of the tissues - comparable in degree and duration to the loading imposed during mastication - would be involved in the exercise of the clenching habits which produced this distinct type of attrition on acrylic teeth.

V

SIMULATION OF ATTRITION.

Among patients who seek advice about difficulties which seem to arise from an intolerance of the denture-bearing tissues for the stresses transmitted by the dentures, the distinct type of attrition associated with clenching and grinding habits can be detected on the teeth. It was of interest, therefore, to investigate the mechanical conditions in which such wear of acrylic teeth can be produced.

The wear resistance of acrylic has been the subject of several investigations recorded over recent years.

Beall (1943) made replicas of the dentures of two patients on insertion, and measured the wear of the teeth after 4 and 7 months' use respectively. It was demonstrated that the rate of wear of the acrylic teeth in one of the cases, in which the patient chewed tobacco regularly, was greater than in the other, but the short duration of the observations did not allow a general assessment of overall wear.

Saffir (1944) reported on abrasion resistance of acrylic on the evidence of tests using a Tabor Abrador, which produces wear by the action of felt pad wheels filled with emery.

Boddicker (1947) compared the abrasion resistance of acrylic, porcelain and gold in teeth under loads of 6 lbs. for 10 hours, followed by one hour under a 6 lb. load with an abrasive present, and finally under a load of 25 lb. for one hour. These experiments used a Kelly grinder.

Cornell et al. (1957) also compared wear resistance of various materials used for artificial teeth by means of long term testing of opposing pairs of single first molar teeth, and they measured the resulting wear in terms of weight loss.

Since none of the tried methods of assessing wear resistance of acrylic teeth could give an indication of the conditions of loading which could produce observed degrees of attrition on a complete artificial dentition, because they were designed rather to compare wear resistance of various materials, a new approach was required. This was undertaken with the advice and technical facilities of the Bio-Engineering Unit of the Department of Mechanical Engineering of the University of Strathclyde, which is engaged largely in investigations of the structure and mechanical properties of tissues and the engineering principles underlying their function. (Kenedi, 1963).

It is recognised in engineering practice that several factors combine to determine the amount of wear of a material which will occur in a given situation. The hardness of the materials and the areas in contact, the surface contours, the pressure between the surfaces, their relative speed of movement, the internal structure of the materials and their physical and chemical environment all play a part. (Burwell, 1950). This being so, reliable indications of the wear to be expected are best obtained by attempts to simulate the conditions of the actual use of the parts during laboratory tests.

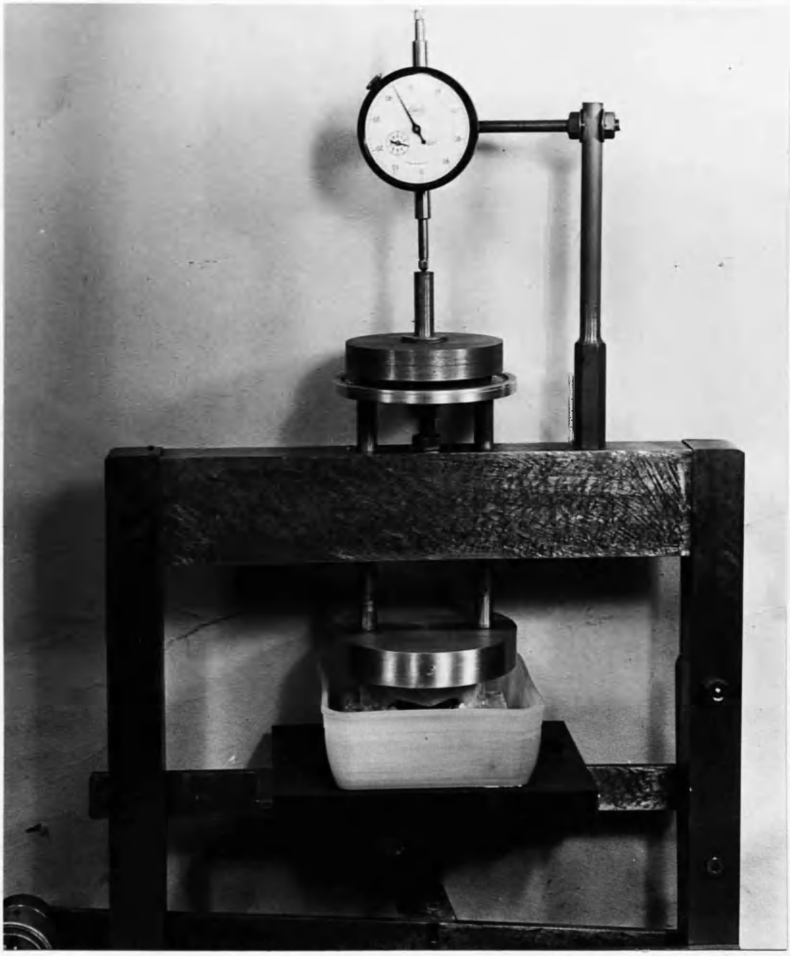
To this end, apparatus was developed through the co-operation of engineers and engineering technicians with the author in design and construction. The apparatus was made to be capable of producing simulated attrition of complete sets of acrylic posterior teeth by causing them to move in a way similar to that of their use in the mouth while held in occlusal contact under loads within the range of masticatory function. (Thomson, 1965).

Development of apparatus.

A first attempt made use of a proprietary denture-grinding instrument, the Dox Grinder, which was coupled to an electric motor to provide for continous testing over long periods. Although small loads of two pounds only were applied, it was soon apparent that this instrument, designed for hand operation for short periods using abrasives between the teeth, was not capable of withstanding the wear and tear involved in long-term use. This was a first impressive demonstration of the great mechanical stresses imposed upon the structures which supported the teeth under conditions producing wear of their occlusal surfaces. More robust apparatus with hardened steel bearings and precisely fitted parts had to be constructed to withstand the stresses imposed and to permit accurate measurement of the resulting wear of the teeth. (Fig. 21).

To simulate masticatory movements, the lower teeth were mounted on a cam-operated platform which caused them to rise to make contact with the uppers at a suitable point in each cycle of movement. The upper teeth were free to move vertically when the thrust was applied from the lowers, and a known load was applied by a suitable weight being placed on the platform on which the upper teeth were mounted. This produced a condition simulating the pear-shaped path of lateral movement of the mandible during mastication. Wear of the teeth produced by the use of this equipment was similar in appearance to the attrition seen on acrylic dentures worn by persons who practise a tooth-grinding habit.

FIGURE 21.



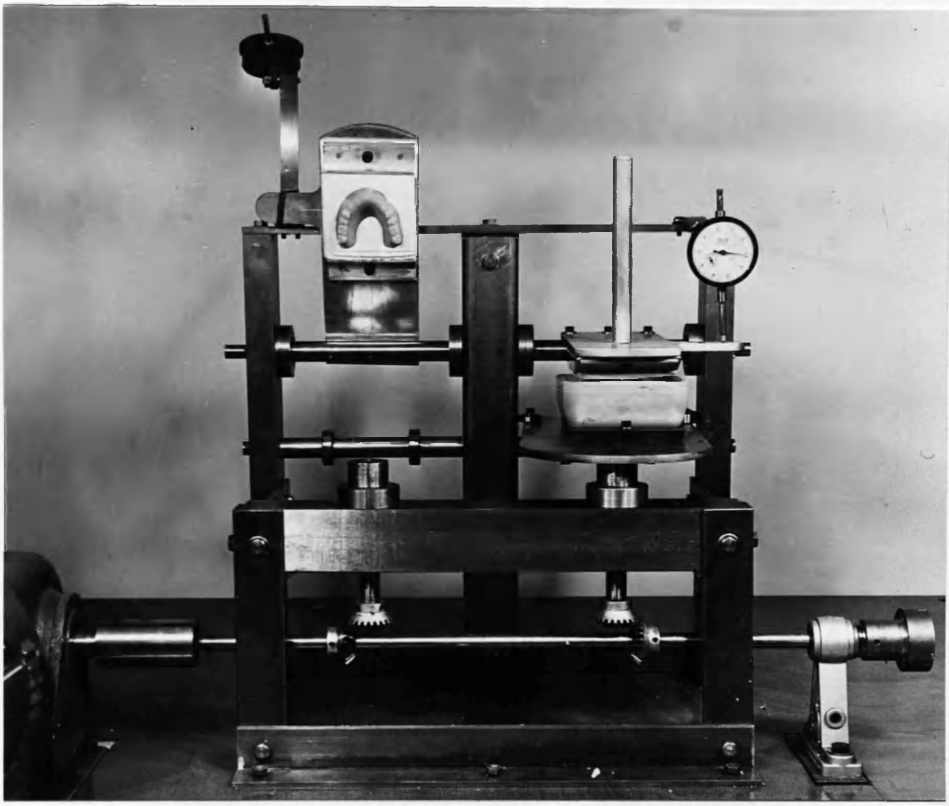
Apparatus first developed to simulate attrition of complete sets of acrylic teeth under known conditions.

Assessments of the amount of wear were made by measuring the loss of vertical tooth height occurring every 24 hours.

This apparatus was used in preliminary tests, during which experience was gained in judging the appropriate speed of movement, amplitude of stroke and range of loads. Then further testing equipment was made. (Figs. 22, 23 and 24).

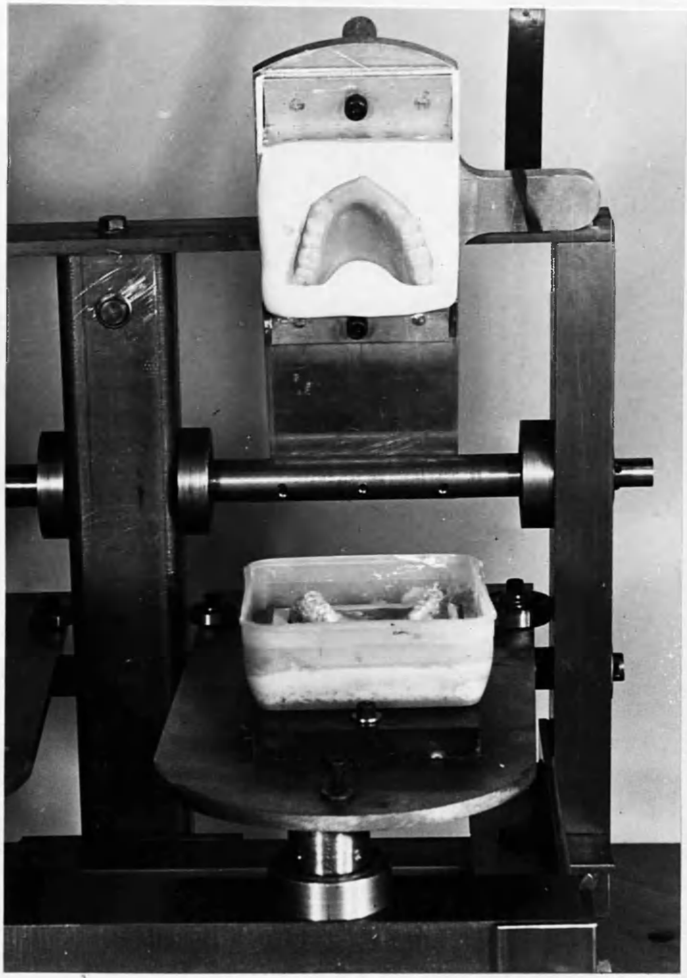
Ultimately an apparatus was designed to cause the lower teeth to move horizon tally, being mounted on a platform which is pivotted anteriorly at a point 5/32 in. off centre to a vertical shaft rotating at 60 revolutions per minute. The rear of the lower platform moves on ball point bearings and is restricted to move mainly antero-posteriorly. The upper teeth are mounted so as to maintain continuous contact with the lowers under known loads. The occlusion of the teeth resulting rom this arrangement is not a rigid mechanical rotary grinding action, but allows for cuspal guidance to influence the path of movement. The wear produced by this horizontal continuous contact action is comparable with that produced by the earlier

FIGURE 22.



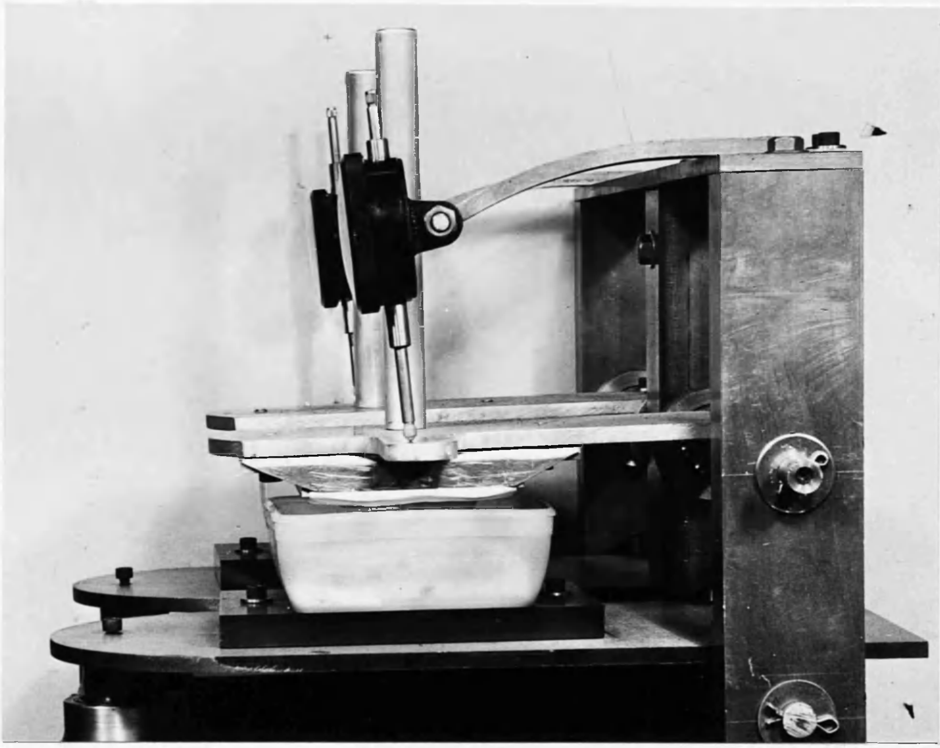
Apparatus used in obtaining the results reported, producing a continous contact of the teeth and a lateral and protrusive grinding action.

FIGURE 23.



Details of the mechanism.

FIGURE 24.



Apparatus viewed from the side.

pear-shaped movement, and this system has the advantage of saving testing time, since the previous arrangement involved intermittent wearing contact of the teeth for only one third of each cycle. Although not strictly analogous to masticatory movements it would seem to simulate the movements of a tooth-grinding habit even more closely.

An assessment of the amount of wear which is produced is obtained from a dial gauge mounted so as to record the distance between the platforms on which the teeth are mounted, and indicated the reduction in height of the teeth due to wear of the occlusal surfaces as tests proceed. Since various parts of the tooth surfaces show greater or less wear at different stages of each test, it was found necessary to record changes of tooth height at several positions of occlusion. The positions chosen correspond to the centric, protrusive, and extreme lateral points of each cycle of movement, so that four readings of the dial gauge are used to represent the tooth wear occurring during each period, usually of 24 hours. (Table IV). The aggregate of these four readings is taken to represent the rate of wear of the whole tooth surface.

Method.

For the experiments, full sets of posterior teeth are mounted on acrylic blocks to occlude as in full dentures. The specimens are fixed on the platforms of the apparatus, in occlusion, and appropriate loads are applied. The dial gauge recording the initial tooth height is adjusted, and the readings noted. The motor is started and allowed to run continously for 24 hours, when further readings of the dial gauge record the loss of tooth height produced. The initial wear on each specimen tested usually involves the reduction of a few "high spots" on the occlusal surfaces, and this may be inconsistent with the later pattern.

During tests the teeth are immersed in water, which serves to remove acrylic debris from between the tooth surfaces since the continual agitation of the water-bath,

TABLE IV .

An example of a laboratory record of a wear test on acrylic teeth.

Day	Load (lbs.)	Dial gauge readings (1/1000 in.) 1	2	3	4
1	10	500	534	539	530
2	10	497	523	538	528
3	10	497	521	536	526
4	10	496	520	535	526
5	10	496	519	534	525
6	10	495	519	532	524
7	10	494	517	530	524
8	10	492	515	529	524
9	10	492	513	528	523
10	10	492	511	527	523
11	10	492	511	527	523
12	20	488	501	519	514
13	20	480	498	511	506
14	20	474	494	504	501
15	20	470	484	497	491
16	20	470	484	497	491
17	20	469	482	496	490
18	20	469	481	495	490
19	20	468	480	494	490
20	20	468	479	494	489
21	20	467	479	494	489

which rests upon the moving platform, produces a useful flushing action. Preliminary tests in dry conditions showed a degree of abrasion caused by the debris which tended to collect. Attempts to introduce abrasives such as pumice and alumina purposely were unsuccessful, since the movement of the apparatus caused the powders to settle in the base of the container instead of remaining in suspension and so being interposed between the tooth surfaces. Additives such as glycerol and sucrose were found to have no effect.

So the experiments were carried out with the teeth under water in conditions similar to those obtaining in the mouth of a person practising non-functional tooth-grinding movements of the jaw.

Results.

A series of tests has shown that wear of acrylic teeth similar in type to that seen on the dentures of patients who habitually grind their teeth together is produced under the attrition-simulating conditions adopted.

Porcelain teeth have been used in a number of the experiments, and the results show a pattern of wear similar to that found with acrylic teeth, although the total wear was somewhat less. However, when heavier loads, e.g. in the 20 lb. range, were used, chipping of the porcelain teeth occurred.

When porcelain teeth were opposed to acrylic teeth, the wear was entirely at the expense of the acrylic, and was moderate in degree, but if the surface glaze of the porcelain had been removed by preliminary grinding on a carborandum wheel the rate of wear of the opposing acrylic was markedly increased. In the case of acrylic being worn against glazed porcelain, however, the persistence of the conical cusp form of the porcelain teeth tended to produce grooves in the opposing acrylic. The cuspal guidance which the apparatus allows then permitted the path of movement to be guided by these grooves, and the areas subject to wear were thereby limited. The reduction of occlusal height recorded was consequently increased disproportionately to the amount of wear of acrylic material which was occurring.

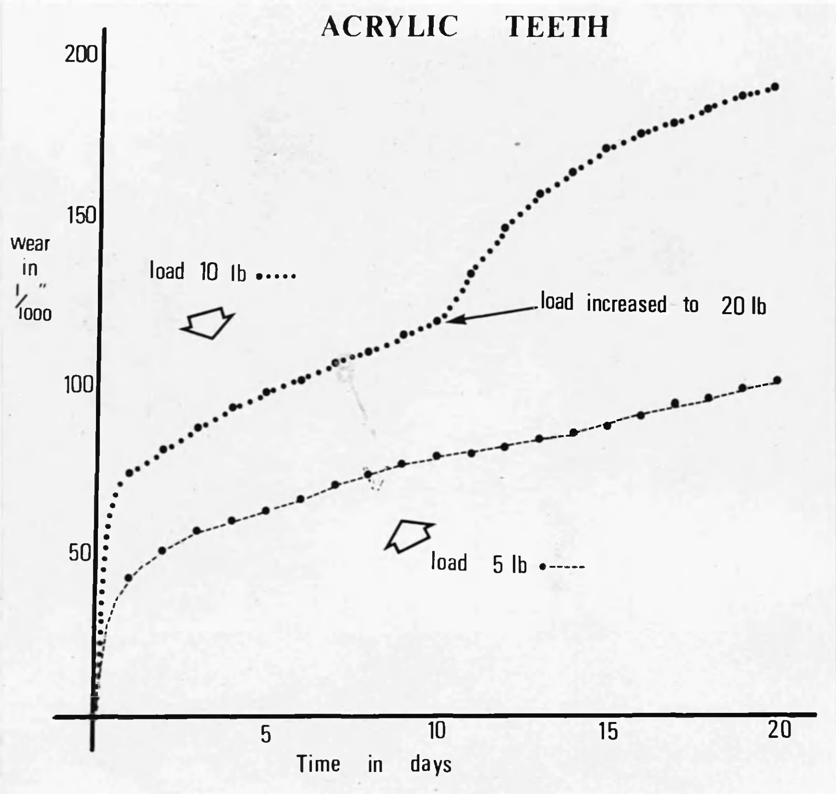
Comparison of two types of acrylic teeth, one of which was claimed by the manufacturers to be especially resistant to wear, showed no significant difference in wear resistance.

Typical results obtained during the experiments are displayed graphically in figures 25to 29. In general the loss of tooth height recorded varied with the load applied and with the areas of tooth surfaces in contact at succeeding stages of tests.

Discussion

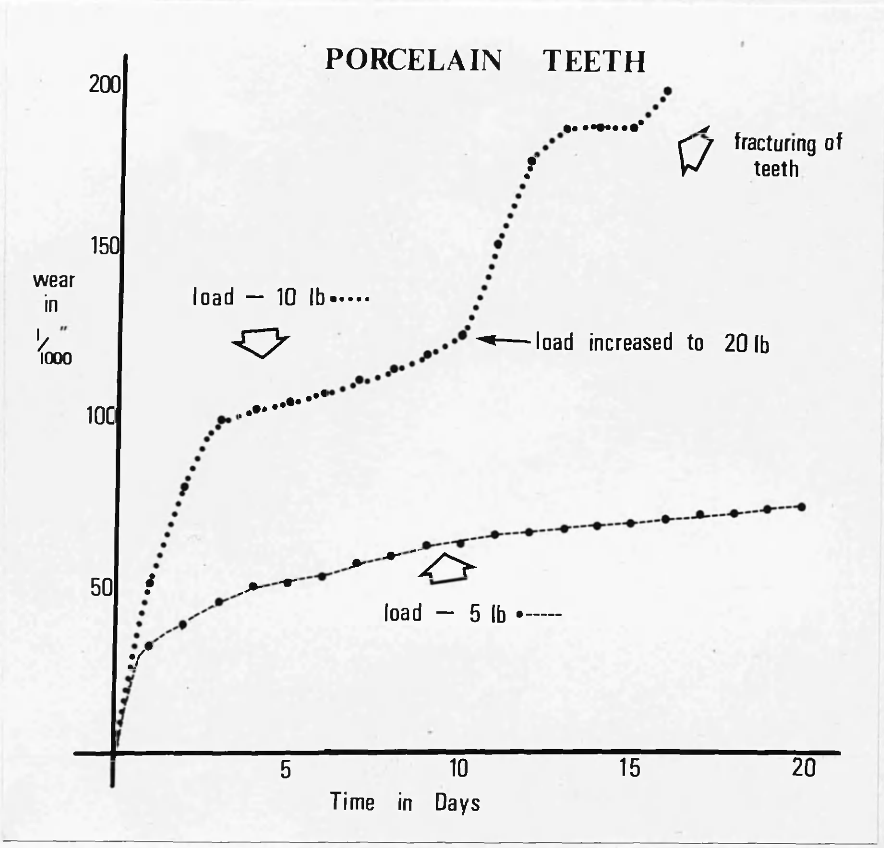
These results may be related to clinical observations. The illustrations in Figure 30show a comparison of actual and simulated wear of acrylic teeth. In interpreting these appearances, it should be noted that the amplitude of the grinding movement used during the experimental simulation of attrition was such that the posterior teeth used were caused to involve their whole bucco-lingual width during each cycle, - once every second- which would represent a very vigorous and sustained activity of the jaw in a patient. Most tooth-grinding habits are less energetic or they would be much more apparent.

FIGURE 25.



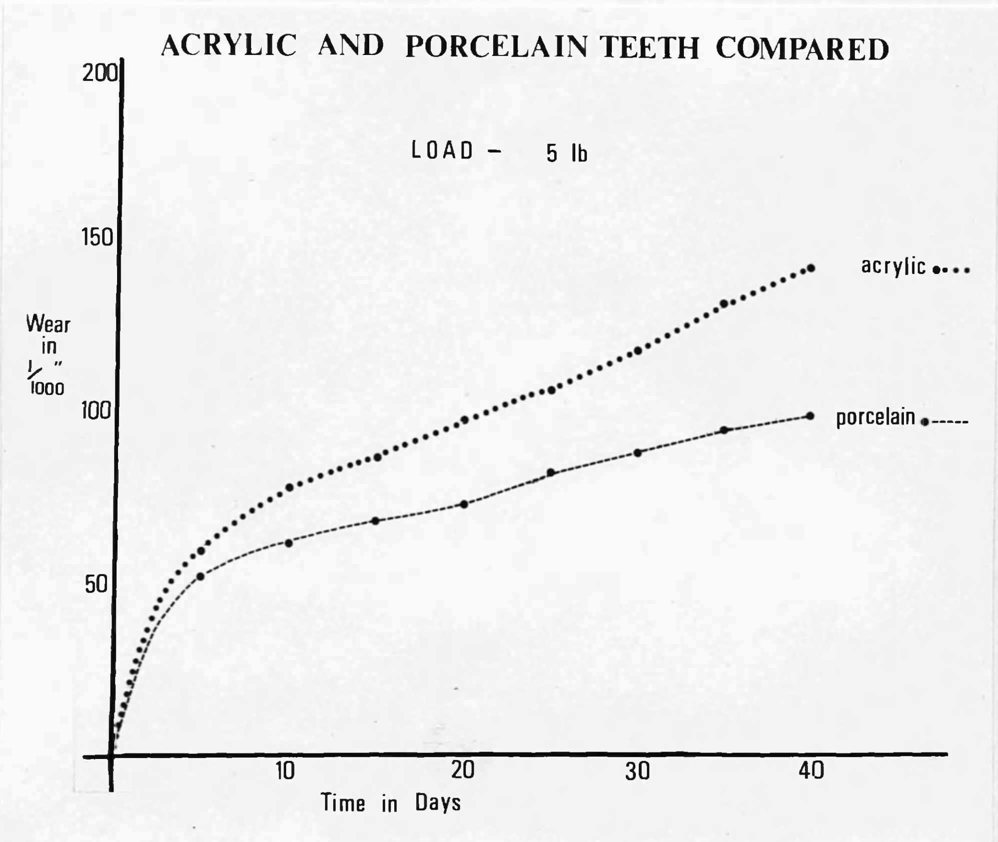
Wear of acrylic teeth under varying loads.

FIGURE 26.



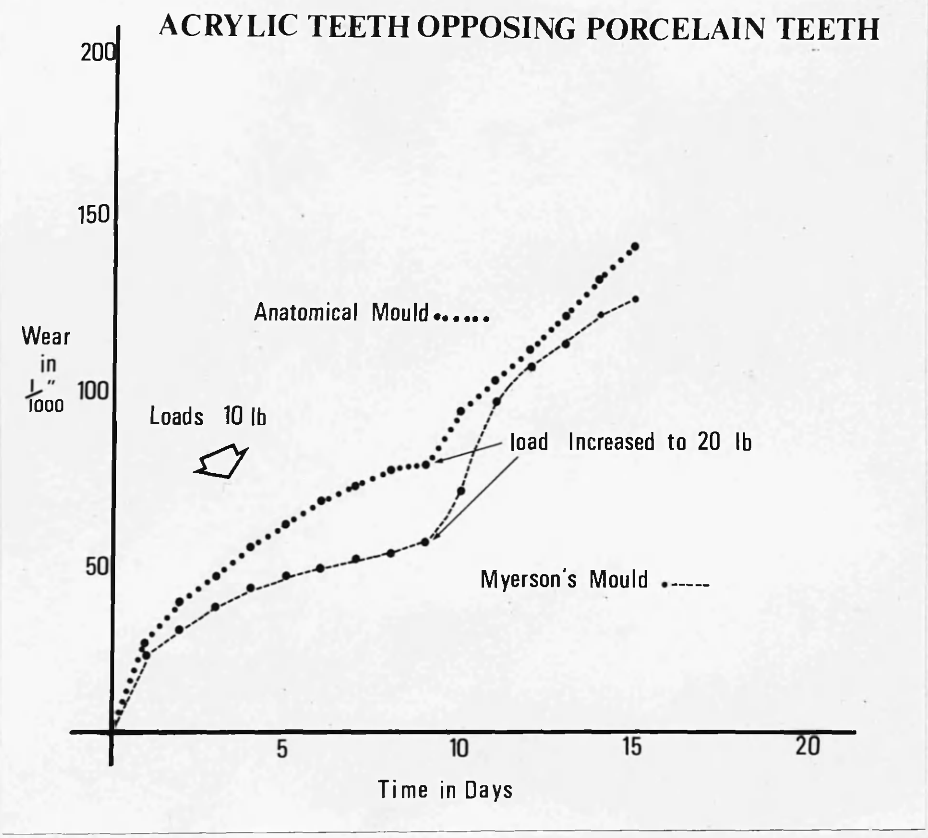
Wear of porcelain teeth under varying loads.

FIGURE 27.



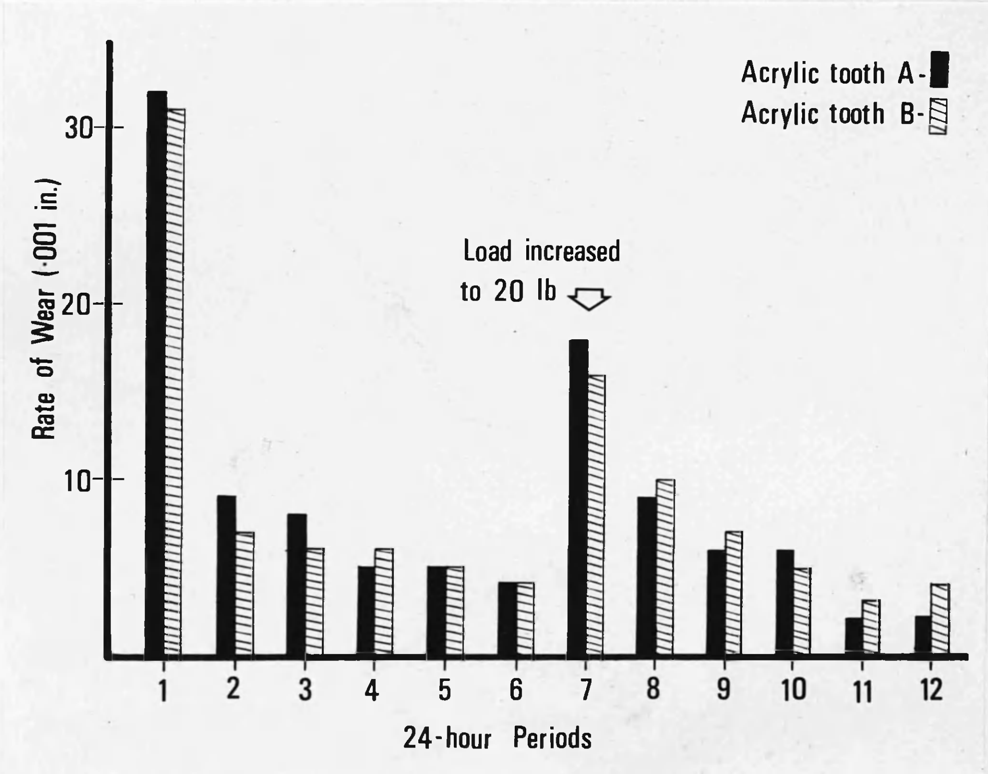
Comparison of wear of acrylic and porcelain teeth under the same load.

FIGURE 28.



Wear between acrylic and porcelain teeth - comparison of two forms of mould under the same conditions.

FIGURE 29.



Comparision of two brands of acrylic teeth of the same mould form under the same conditions of wear. One was claimed to have superior wear-resisting qualities.

FIGURE 30.

Comparison of the appearance of a specimen (left) after simulated attrition of 240 hours under a load of 10 lbs. followed by 240 hours under a load of 20 lbs., with an acrylic denture which had been worn for 15 months by a patient who habitually grinds his teeth.

For instance, when the teeth are habitually merely clenched or clamped together, with little or no movement between the opposing surfaces, a lesser degree of attrition is produced, although the loads may be very great. The chipping of porcelain teeth which arose when these were tested on the apparatus is an indication of the severity of the tests. In the mouth this does not usually occur, and indeed any activity which might cause it would be avoided because of its unpleasantness.

The loads used were within the range recorded in studies of the loads on teeth during mastication, to which reference has been made. The duration of actual tooth contacts occurring during mastication was assessed by Sheppard and Markus (1962) by a cinefluorographic method allowing observation of all possible tooth contacts, which were timed. This resulted in a maximum number of contacts being recorded, but was thoughtto include instances which appeared radiographically to be actual tooth contacts, but in which occlusion may not in fact have occurred. On this basis these investigators concluded that the duration of all tooth contact occurring during mastication must be less than 12 minutes per day. Brewer (1963) using radio telemetry, calculated a daily total of 5 minutes of tooth contact during chewing, but recorded contacts during sleep varying from 5 minutes to $2\frac{1}{2}$ hours in one night in different subjects. He added the comment that "many of these contacts are grinding, not just holding".

Further interpretation of the results of these experiments must be approached with caution.

The loads used in the simulation of attrition were applied to a full complement of artificial posterior teeth, and are equivalent in total to the loads which would be distributed over the denture foundation in a living subject. Except in the case of a perfectly balanced articulation, however, there will be unequal distribution of pressure at different parts of the denture-bearing mucosa during various phases of opposing tooth contact, and idiosyncracies of each individual affecting patterns of jaw movement would add further complications.

The distribution of the load will vary also with the thickness and resilience of the soft tissues interposed between the denture base and the bone, and with the contour of the bone of the jaws and the character of its surface. The relationship of the dental arches to the residual alveolar ridges, which is dictated to some extent by aesthetic considerations and the functional position of the tongue, cheeks and lips, is another factor influencing the distribution of the load over the denture-bearing area. The area available for the support of full dentures has been shown to vary widely between the upper and lower jaws and between individuals. Other factors being equal, it would be tempting to express the pressures upon the tissues as the quotient of the total load and the vertical support area, e.g. the load of 10 lbs. used in the experiments might be divided by the average denture-bearing area previously computed for the lower edentulous jaw (1.90 squ.in.). An average pressure of 5.26 lbs. per squ. in. would be derived from this exercise.

However, the distribution of pressure upon the denture-bearing mucosa is uneven, being subject to the other variable factors already mentioned, and this invalidates the conception of an average pressure based only upon the total load and the total area in any given case. Nevertheless, the total denture-bearing area available and the total load applied to the teeth and transmitted to the tissues remain as important factors which vary between individuals and may govern the adequacy of the support of full dentures.

The experimental data, as recorded graphically, shows that if attrition is produced by small loads, e.g. 5 lbs., the grinding activity must be continued for a very long time to produce more than a slight facetting of acrylic teeth. Only when loads are used which are equivalent to, or greater than, those which have been demonstrated by denture-wearing subjects during biting and chewing, was the attrition rate much accelerated.

Either circumstance - very heavy loading or high frequency and duration - may occur in habitual non-functional occlusion. Both conditions may be expected to produce discomfort in denture-bearing mucosa.

Conclusion.

The objective of the experimental simulation of attrition was to assess the significance of the attrition which can be observed clinically in terms of the additional load which the denture-bearing tissues may be required to support. It was doubtful whether to produce attrition of acrylic teeth by tooth-to-tooth contact required the application of forces comparable to those involved in normal jaw function.

The experiments undertaken seem to suggest that attrition of acrylic teeth of the type produced by actual tooth contact is an indication that the tissues supporting the dentures have been subjected to loading which might be expected in some cases to be a cause of discomfort and intolerance of dentures. To produce attrition between the opposing surfaces of complete sets of acrylic teeth, in the laboratory, equivalent to that observed in the case of patients who habitually grind the teeth of their dentures together, required the prolonged application of a vigorous grinding action under loads similar to the average forces used during chewing with dentures. This represents a formidable addition to the stresses to be borne by the supporting tissues.

VI

DIAGNOSIS OF FAILURE OF SUPPORT.

Patients often give a rather vague account of their difficulties in wearing dentures. Some simply state that the dentures do not fit, and this complaint may mean lack of retention, instability, discomfort, or even dissatisfaction with their appearance. It is necessary to establish, therefore, whether the dentures do stay in place, whether they can be controlled during eating and speaking, whether they cause pain and whether they are thought to be aesthetically suitable.

Diagnosis of the causes of patients' difficulties is a necessary preliminary to treatment. The review by Lawson (1959) of findings on examination of 200 patients who experienced difficulties in the use of full dentures showed that relatively simple faults were frequently found. Under - extension of denture bases was most common, followed in order of frequency by unsuitably placed anterior teeth and unbalanced occlusion.

Errors of the jaw relationship recorded,increased vertical dimension and mandibular protrusion, were found also.

A considered diagnosis made before embarking upon empirical treatment - often a sequence of "easings" and relining - would have indicated suitable and effective remedies.

Retention and stability require prior consideration.

Failure of retention of full dentures is usually evident from the patient's account of his difficulties. Relevant factors to be considered in determining the cause will include the accuracy of the baseplate, the adequacy of the peripheral seal, the functional depth of the sulci and the contour of the lingual and facial surfaces of the denture.

Instability may be suggested by reports of movement of the dentures during function or because of signs or symptoms - ulceration or pain - caused by abrasion of the tissues by movement of the dentures.

The cause may be determined by examining the occlusion of the teeth and the relation of the dentures to the alveolar ridges, the tongue and the cheeks.

Failure of support is usually accompanied by a complaint of pain or discomfort of the denture-bearing areas of the mouth.

In diagnosing the cause of pain or discomfort of the denture-bearing area, instability of the dentures must be eliminated first. Then physical signs will serve to indicate causes of localised discomfort such as over-extension of baseplates, retained roots, torus palatinus, and other irregularities of the bony foundation. When more generalised pain or discomfort is accompanied by widespread inflammation of the mucosa, the traumatic and inflammatory factor involved in denture sore mouth must be sought. Matthews (1954) emphasised the role of rough tissue - fitting surfaces on dentures as a frequent cause of discomfort. The occurrence of sharp spicules of bone on the crest of the alveolar ridge is another cause of pain in mucosa, which is sandwiched between the denture base and the bone.

Systemic factors have been considered by some authors to be important in cases of reduced tolerance of the tissues to denture-bearing. Kimball (1954) mentioned drugs, allergy, debilitating disease, endocrine imbalance and blood dyscrasias, and laid special emphasis on nutritional deficiencies as an underlying cause of low-grade inflammatory conditions of the oral mucosa.

Sharp (1960) advocated nutritive supplements in treating cases of low tolerance to dentures which showed atrophy and inflammatory signs in the mucous membranes. Kim, Ringsdorf and Cheraskin (1962) considered local and systemic factors affecting denture tolerance, and suggested that systemic factors are more highly correlated to oral signs and symptoms than are local factors. Again, nutritional deficiency was given special attention.

Xerostomia, as encountered in Sjogren's syndrome, can be readily recognised as a cause of tissue discomfort beneath dentures.

In all the conditions mentioned so far as causes of discomfort of the denture-bearing tissues, physical signs of trauma or inflammation are present and assist diagnosis. In other cases, however, physical signs may be absent or very difficult to discern. The mucosa may appear quite normal, but subjective symptoms sufficient to prevent the continuous use of the dentures may be present.

The discomfort varies in degree. It may be described as a continuous irritation of the soft tissues, causing the patient to unseat the denture from its foundation at intervals to obtain relief: or it may be presented as pain of a throbbing or burning nature. The discomfort may be localised, varying in location, or diffuse, within the denture-bearing areas of the mouth, but the most common sites are the crests of the alveolar ridges and the anterior part of the palate. Irritation of the tongue and the lining mucosa of the lips is sometimes an accompanying and related feature. Sometimes an intolerable tightness of the dentures is described. The symptoms appear within periods ranging from a few minutes to several hours after the dentures are inserted, and are relieved by removing the dentures. Although the discomfort is not related to eating, it may be such that the dentures are not used at meal-times. Patients tend to remove their dentures when the discomfort becomes intolerabe or when social circumstances allow. This situation may prevail for long periods of weeks or months, or it may occur only for a few days at a time, with intervening periods of comparative comfort.

Excessive loading of the denture-supporting tissues seems to be the basic cause of these symptoms.

Selected Case Histories.

A few actual case histories will serve to indicate the aetiology of cases in which excessive load leads to failure of support of full dentures.

(i) The case of the patient who had worn dentures for four years, but had required several "easings" during the previous few months, is not uncommon. Since the dentures were in quite good order and the baseplates still fitted well, her dentist did not see any reason for replacing them, but she complained of pain on the anterior aspect of her lower alveolar ridge. On examining the occlusion of the teeth, it was noted that no overjet existed between the upper and lower incisors, and that the posterior teeth had become slightly worn down. It appeared that a suitable relationship of the incisors had been provided when the dentures were first made, but wear of the posterior teeth had altered this. (Fig. 31).

FIGURE 31.

Wear of acrylic posterior teeth
resulting loss of incisal overjet.

Contact of the incisors eventually placed undue load on the anterior part of the lower ridge.

(ii) A full lower denture case was seen nine months after it was first inserted. During this time much effort had been expended on adjustment of the baseplate by removal of parts of the periphery adjacent to painful areas. The vertical dimension of the occlusion did not allow a free-way space, and the baseplate did not utilise all the available denture-bearing areas of the alveolar ridge. Repeated "easings" may have accounted for some of the inadequate coverage evident when the case was seen. The lack of free-way space, and consequent continuous loading of the denture-bearing mucosa,was the cause of the discomfort in this case.

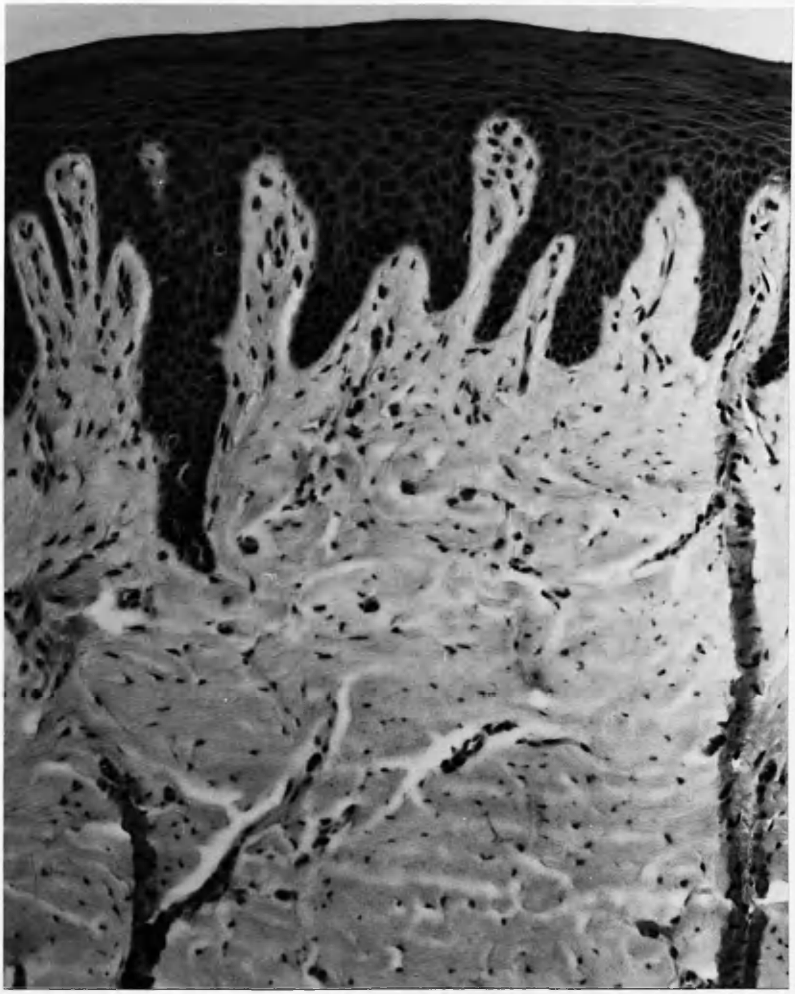
In these two instances the excessive loading of the tissues was due to faults in the dentures which could be recognised on examining the patient, although the mucosa bore no physical signs. In other cases, unusually severe conditions of loading are the primary cause of intolerable stress on the tissues supporting dentures, but the signs may be more difficult to discern.

(iii) For example, a woman who had persevered with new dentures, at intervals, over six months, complained of discomfort in the left premolar region of her lower ridge. There was nothing abnormal to be seen on examining her mouth, the dentures seemed in all respects suitable, but very small polished facets were noted on the buccal cusps of the upper and lower premolars on the left side. There appeared to be adequate provision for balance in normal lateral excursions of the mandible. She was able to produce here previous dentures, the occlusion on which seemed to have become adapted to an unusual position of right lateral posture of the mandible. This seemed to have been a habitual posture when the old dentures were in use. The small facets on the new dentures indicated an attempt to continue the habit, which with the new occlusal pattern led to unduestress on the left side of her ridge.

Since her discomfort was localised to one area, the possiblity of a local irregularity of the alveolar bone was considered, and this was investigated by reflecting the mucous membrane to allow direct examination. The crest was smooth and in tact. A small piece of tissue was removed at this time and prepared for histological examination. Fig 32 shows the appearance of one section. A slight increase in the thickness of the keratinised layer may be discerned in the central part of the section, at the summit of the crest, as compared to the areas on each side which represent the buccal and lingual slopes of the ridge. There is no evidence of deterioration of the mucosa in the histological picture of this tissue from an area of considerable discomfort to the patient.

(iv) More generalised discomfort affecting the crest of the lower alveolar ridge was reported by a patient whose rather old dentures had been replaced one year

FIGURE 32.

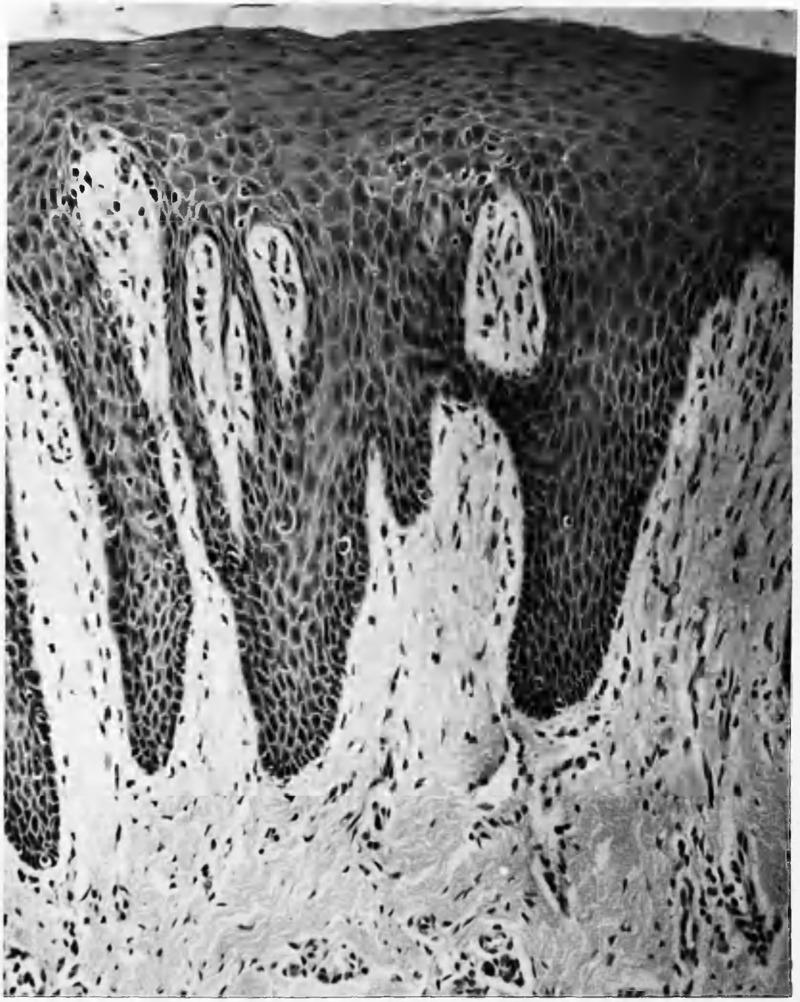


Section of tissue from a painful area on the crest of the alveolar ridge.

previously. The more recently - made dentures seemed to be satisfactory from a prosthetic point of view, and the denture bearing mucosa appeared normal. Some hypertrophied tissue - a relic from her previous ill-fitting denture - remained in the lower buccal sulcus, but the new denture had been made to avoid this area. It was thought advisable to excise this hypertrophied tissue to allow fuller extension of the flange of the denture, and in the course of this operation a biopsy was obtained from the crest of the ridge - an area which formed part of the widespread zone of discomfort.

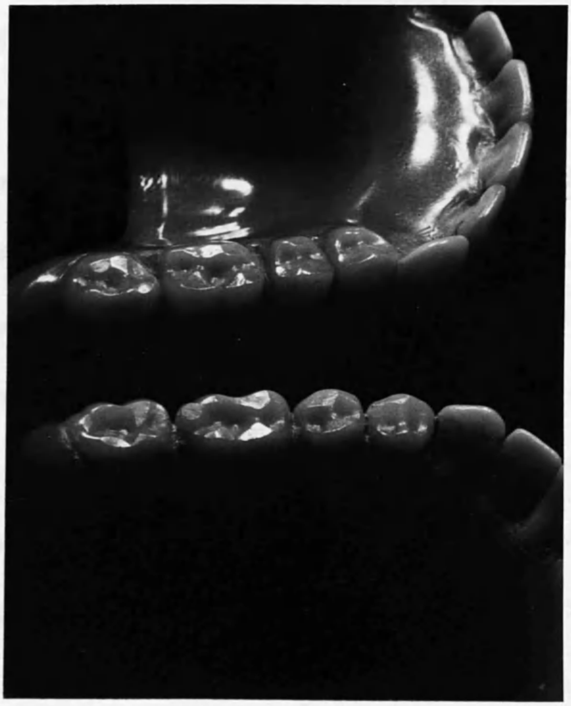
The tissue from the ridge appeared healthy on histological examination, as shown in Fig. 33. Again one might consider the epithelium to be typical of a not unfavourable reaction to denture bearing. As illustrated in Fig. 34 , attrition facets caused by persistent tooth-clenching were evident on the occlusal surfaces of the teeth of the denture. It might be supposed that the habit arose during the period of

FIGURE 33.



Section of tissue from the crest of a lower alveolar ridge subject to generalised discomfort, associated with a tooth-clenching habit.

FIGURE 34.



Attrition of teeth on dentures in a case in which the patient clenched her teeth, and complained of generalised discomfort of the lower alveolar ridge.

attempting to accommodate to the new dentures, which may be difficult for a patient who had been long accustomed to old ones. But clearly excessive loading due to the habit was the cause of considerable discomfort, although the mucosa was normal.

(v) A keen salesman complained that continual discomfort with his full upper denture intruded upon the concentration which his work demanded. To relieve the discomfort he was accustomed to dislodge the denture momentarily by deliberate movements of his upper lip, which manoeuvre, he said, was distracting to his customers. His acrylic upper teeth were opposed by a natural lower dentition which presented an uneven occlusal table. The upper acrylic teeth had been worn to a correspondingly irregular occlusal surface, and imbalance occurred in certain eccentric contacts. During intervals in the dialogue when he was listening rather than speaking, it was noticed that his masseters were frequently contracted, clenching the teeth alternately in one position and another.

In this case the tooth clenching habit was clearly causative of the discomfort, but the general picture of a rather tense and demonstrative person suggested that the occlusal habit and consequent imbalance of the denture which caused the discomfort may have been secondary effects of a centrally initiated muscular activity. Indeed when the clenching habit was pointed out as a cause of his discomfort, he indicated that it was for him an inseparable part of the concentration required for success in his work. However, after new dentures had been fitted he reported complete relief. The upper denture was made with porcelain teeth and with labial flanges shaped so as to prevent easy dislodgement of the denture by the lip, and an overlay was applied to the lower teeth to regularise the opposing occlusal table. It seemed, therefore, that the unfortunate habit was at least aggravated by the local conditions, since it disappeared when they were altered by the new dentures, but it is not possible to assess to what extent the patient may have been able to control his mannerisms by deliberate decision and effort.

(6) In another case the primary effect of a tooth-clenching habit was clearly demonstrated. This patient had experienced discomfort of varying intensity in his lower alveolar ridge for many years, and had sought relief many times. Surgical measures to improve the lower denture bearing area had been attempted without success, and when first seen he was wearing a lower denture lined with black gutta percha, a procedure which seemed to have been adopted as a last resort. The dentures seemed suitable in fit and occlusion, and the form of the edentulous mouth was not unfavourable for a satisfactory restoration. The mucous membrane was healthy and free of inflammatory signs.

Although no obvious facets could be seen on the porcelain teeth of his dentures, the possible involvement of a tooth-clenching habit was considered, and this possibility was proposed to the patient. He thought this to be unlikely, since he was unaware of practising any such habit during the day and he did not wear his dentures at night. He was aware, however, of a general sense of tension which he experienced during periods of extra pressure of work or business anxiety. No conclusion or solution to his denture difficulties could be suggested at that time. Later, however, the patient was seen again at a time when the discomfort had intensified.

Enquiry revealed no evidence of unaccustomed smoking, alcohol, mouthwashes or denture cleansers being responsible, but the patient himself spoke again of a period of "tension", and had noted now that he clenched his teeth when these circumstances prevailed. This seemed to be the cause of his discomfort, and the explanation of excessive pressure on the mucosa was readily appreciated by the patient as the factor responsible. There followed a period when various modifications of denture design were tried in the hope of removing any local irritation which might have a trigger effect. Variation of vertical dimension of occlusion, arch size and occlusal pattern produced some slight improvement, but still at intervals the discomfort became difficult to tolerate. The case was later referred for treatment by hypnosis. By this means a comparatively relaxed state could be induced during the periods of stress, and this in turn produced remission of the intolerance of the dentures. In this case local measures failed to eliminate the para-functional muscle activity which produced over-loading of the denture-supporting tissues.

Discussion.

The relationship of pain and discomfort of the denture-bearing tissues to an excessive vertical dimension in occlusion, and absence of separation of the teeth in the rest position of the jaws, is recognised in clinical practice. Lawson (1959) described the typical symptoms - indeterminate pains, increasing as the day passes and associated with a feeling of tiredness of the jaws, relieved by removing the dentures - and he commented upon the absence of ulceration of the mucosa. Mack (1964) recognised "open bite" as a cause of general pain affecting full denture wearers, due to the "constant load being exerted on the denture-bearing area".

Mucous membrane is sensitive to pain in response to many kinds of stimuli, of which pressure is one. Samson Wright (1961) considers that pain in response to compression of nerves is probably due to interference with their blood supply. Complete ischaemia leads to loss of sensation in the enervated region, but lesser degrees of compression, or intermittent compression, may increase the irritability of the nerves and lead to paraesthesiae or hyperalgesia. "Thus normally sub-threshold stimuli became painful".

This would seem to explain the pain and discomfort occurring in association with excessive vertical dimension in full dentures, and in the absence of signs of trauma of the mucosa.

An increased load on the mucosa similar to that associated with open bite seems to result from the practice of non-functional habits of occluding the teeth, and similar symptoms of discomfort and consequent intolerance of full dentures are the result. When the cause is a tooth-clenching or tooth-grinding habit, the discomfort may be intermittent, with remission of symptoms corresponding to periods when the patient may be less tense and more relaxed.

Non-functional habits of occluding the teeth.

The choice of a suitable term to describe habits involving repeated or sustained occlusion of the teeth, not associated with mastication or swallowing, is difficult. "Bruxism", which by its derivation is descriptive of grinding or gnashing or clenching of the teeth, has now acquired a rather restricted meaning and is usually understood as referring to severe grinding of the teeth during sleep, recognised by the noise of gnashing and the gross attrition produced.

The term "bruxomania" is commonly used to describe extreme manifestations of tooth-grinding activity occurring while the subject is awake, and it seems to presuppose a psychological cause which may not be appropriate in many cases. A similar objection arises in the connotation of the term "occlusal habit neurosis" proposed by Tishler (1928), who nevertheless recognised local occlusal irregularities as well as psychological factors in the aetiology of the condition.

The aetiology of non-functional habits of occluding the teeth has been considered by several authors. Nadler (1957) reviewed early opinions about bruxism and produced a classification of the many contributory causes which had been suggested. Local causes, mainly occlusal disturbances, were thought to induce bruxism as an unconscious attempt to counteract local irritating situations. Systemic causes listed included gastro-intestinal disturbances, nutritional deficiencies and endocrine disorders. Psychological causes were in the categories of emotional and mental stress and mal-adjustment. Occupational causes were separately classified, but seemed to involve again a response to stress in such persons as athletes and precision workers. "Involuntary" forms of bruxism form another category in Nadler's classification, used to include stress situations such as motoring, service in the armed forces and study and concentration.

Habits of chewing gum and biting pencils were considered analogous to bruxism.

Drum (1962) used the term "parafunctions" to avoid the suggestion of referring only to neurotic phenomena. He classified these para-functions into five groups.

1. Psychically motivated or largely neurotic symptoms which respond to psychotherapy or restraining devices such as dental splints.
2. Stress motivated habits occurring during intense concentration, anxiety, physical effort or pain, which may be eliminated merely by informing the patient.
3. Habitual para-function associated with activities such as chewing pencils, biting pipestems, and the use of the teeth by tailors and shoemakers.

4. Endogenous muscle contractions related to disease, as in epilepsy or trismus due to infection.

5. Excessive - compensating reactions to occlusal interference produced by faulty restorations or malocclusion following loss of teeth, which patterns of jaw movement may not adapt to accommodate.

This classification is useful since it indicates possible causes and approaches to treatment.

Cases in which xerostomia was associated with bruxism were reported by Roth and Spasser (1957). Emotional disturbance was found to be related to these conditions, and they were relieved by psychiatric treatment.

Berlin and Dessner (1960) reported chronic headache associated with bruxism, occurring during both day and night, and noted also the possibility of temporomandibular joint dysfunction being an allied condition, with pain of muscular origin. They distinguished isotonic or dynamic muscle activity, in which alternate contraction and relaxation of groups of muscle fibres stimulates blood circulation, from isometric or static activity, which imposes a constant strain on the entire muscle with less opportunity for relaxation and recovery, leading to ischaemia and impaired oxygenation, causing pain. Both local factors and emotional tension were held to be responsible.

Tishler (1928) seemed to envisage a combination of local and psychological factors when he stated "Even mild cases of occlusal trauma or minor anatomic defects will receive undue attention by the neurotic individual, resulting in bruxism". This view of the coincidence of two factors is suggested by Miller and Firestone (1947) and Strother and Mitchell (1954). Experimental evidence of abnormal activity of the muscles of mastication was obtained by Perry, Lammie, Main, and Teuscher (1960), who demonstrated that a contrived stress situation induced increased activity of the elevators of the mandible. Ramfjord (1962), again using electromyography and controlled conditions, concluded that occlusal interferences, "when combined with a nervous temperament", may initiate bruxism.

The psychosomatic approach to many ailments tends to highlight neurosis and emotional stress. A proper perspective was suggested by Evatt (1944), discussing "Psychosomatic problems", by his statement that "every patient has somatic and psychological problems, excepting those that are dead when the doctor arrives". Psychological factors, in this view, are universal. One need not expect, then, to find mental ill-health or evident emotional tension as constant precursors of non-functional habits of occlusion. Indeed, in the view of Weinberger (1955) and Every (1960), a vigorous grinding of the teeth may be a healthy and natural response to some situations of normal life.

Leof (1944), in a study of various "clamping and grinding habits", condemned the narrow conception of bruxism as tooth-grinding practiced only when the subject is overwrought or extremely worried. He emphasised, however, the constancy, magnitude and duration of the forces applied to the periodontal membrane as abnormal compared to the forces involved in masticatory function. He described in detail various types of tooth-occluding habits which he had observed. All could occur by day or by night. Clamping habits occurred in centric occlusion, involving sustained or pulsating forces directed vertically or obliquely, and also in protrusive and lateral positions of occlusion. Grinding habits involved slight or extensive movements in lateral and protrusive directions and irregular movements with the lower anterior teeth in contact with the lingual surfaces of the upper anteriors. Clicking habits were also described, in which rhythmic tapping of the teeth was practised in centric, in edge-to-edge occlusion of the incisors, or on one selected tooth. Clamping habits were thought to be most injurious to the periodontal membranes because the forces so involved digressed further from normal.

High incidences of bruxism have been reported in the literature. Boyens (1940) reported on 100 cases in which bruxism occurred in 54 by night and 24 by day. Peterson and Dunkin (1955) reviewed 45 cases, 24 of whom were seen in a general practice and 21 in an exclusively periodontal practice. Their over-all incidence of bruxism in this group was 84.4% of whom 62% practised the habit by day only, 9% by night only, and 13% both day and night.

The incidence of tooth-occluding habits in an unselected group of persons who had used full dentures for 4 years, as assessed during the review undertaken by the present author, was 20%. This figure includes only those cases detected in the course of one interview and examination, and therefore it is probably a low estimate.

The initial discomfort inevitably associated with the fitting of new dentures is knownto evoke unusual patterns of behaviour in the surrounding musculature.

For instance, facial mannerisms are at times responsible for lip discomfort and for dislodging dentures which otherwise are well retained. Complaints of irritation of the tongue are sometimes due to restriction of tongue space within narrow dental arches, but a habit of thrusting the tongue against the denture is not uncommonly found also. The rough surface of which the patient may complain is not, in fact, on the denture, but is a misinterpreted sensation due to irritation of the lingual epithelium. The tongue may "play" with a lingual bar of a lower denture, or tilt an upper one, causing irritation of the tongue and instability of the denture.

Similarly, patients tend to occlude the teeth of new dentures frequently when they are first fitted - perhaps to strengthen confidence in retention or to help retain the dentures until the surrounding muscles accommodate sufficiently to assist in retention. Likewise some accommodation in chewing pattern is usually required, and experimental closure of the teeth is part of the process of adaptation. These early, tentative tooth contacts may trigger a persistent habit, as may other transitory irritations. In prosthetic patients there is considerable possiblity of local causes contributing to the development of non-functional habits of occlusion.

The significance of such habits in causing intolerance of full dentures has been investigated and emphasised in the present work. The loads which they impose upon the denture-bearing mucosa may require more support than the masticating forces to which they become a formidable addition since they may be frequently applied and longer sustained.

Detection of habitual non-functional occlusion.

The diagnosis of grinding and clenching habits is not always apparent, especially when no gross attrition is caused.

When the habit is one of clenching or clamping the teeth, and no grinding movement is used, the attrition facets may be small and difficult to detect, although considerable loads may be involved. Similarly, when the dentures have not been worn continuously due to intolerance of the discomfort, the signs of attrition may be slight.

Deliberate and careful scrutiny of the occlusal surfaces of the teeth under a good light is a useful measure during examination of patients. Attrition facets may vary in angulation, and so be seen only when light strikes them from appropriate directions. This was very apparent during preparation of some of the photographs illustrating this text, when it proved difficult to arrange the angles of incidence and reflection of the light so as to disclose in each photograph even a few of the facets which may be seen on the teeth.

Fatigue of the muscles of mastication may be reported as an ache in the temporal and masseter regions, noticed on waking in the case of a night tooth-grinding habit, or progressing during the day in other cases. A complaint of pressure on the denture-bearing areas of the oral mucosa, sometimes expressed as a feeling of "tightness" of the upper denture is another indication. A typical history is of inserting the denture each morning with reasonable comfort at first, but of increasing irritation causing the patient to remove the dentures after a few hours, or on returning home in the evening, because of intolerable discomfort. A report of intermittent instability of a denture which appears to be well balanced for normal functional purposes is sometimes explained by a patient demonstrating an abnormal jaw movement which dislodges the denture and provides evidence of non-functional habits.

Sometimes these habits may be noted in the course of the interview in the surgery, but it is not usual for the patient to be aware of practising tooth-grinding or clenching when first asked. When his attention has been directed to the possibility, he may return on a subsequent occasion confirming the suggestion from his own observations or those of family or friends. So recognition of the existence of a habit may not be easy for either patient or operator, and its relation to denture discomfort may not be apparent.

The distinct type of attrition previously identified as being associated with forceful tooth contact is a useful diagnostic sign worth seeking. When this has been identified, a further search for predisposing causes is indicated.

It is necessary to distinguish "open bite", which has been shown itself to cause symptoms affecting the support of dentures. So the suitability of the vertical dimension must be assessed with the presence of a free-way space as the criterion. Deliberate attempts may be made to induce the patient to adopt the rest position so that measurements, direct observations or radiography may be used to establish whether a free-way space exists. Certainly these methods are more reliable when the patient has been wearing dentures for some time than when they are applied at the time of registering the occlusion in an edentulous mouth. The past use of the dentures will have helped to establish a normal jaw posture, associated perhaps with a normal tongue position and respiratory function, as suggested by Fish (1964). The patient who has been accustomed for some time to an empty, edentulous mouth is less likely to demonstrate rest position when bite-blocks have just been inserted. Pre-extraction records, in the form of photographs, templates, recorded measurements or immediate dentures, must be regarded with caution also in view of the reduced facial height reported by Tallgren (1957) in patients who had worn dentures for some time, and in those treated by immediate denture prosthesis as reported by Nairn and Cutress (1967). When the free-way space is being assessed in a patient who has been wearing dentures for some time, observation of the teeth during normal conversational speech, or a deliberate evaluation of phonetic function, is the most reliable guide, in one's own experience. Silverman's observation (1956) of the "closest speaking space" may be a valuable adjunct.

Local irritating factors which may predispose to non-functional tooth-occluding habits should be sought. Inadequate retention, occlusal imbalance and restriction of lateral and protrusive movements are the most obvious of these.

The association of systemic factors, mental tension and emotional stress may be usefully considered during consultation, even if the treatment may not be within the province of the dental practitioner.

It is interesting that Stoy (1952) noted that in some of his patients symptoms returned after an emotional upset. Matthews (1954) describes discomfort arising an hour or so after inserting the dentures, and lists occlusal neurosis among the contributory causes. Landa (1945) reported his findings in a group of women aged 46 to 64 years who complained of sensations of burning mouth affecting the anterior part of the palate. Among menopausal disorders which these patients also suffered, he noted mental depression and irritability in most cases. The prevalance of intolerance of dentures at the time of the menopause is noted by Stoy (1952), Matthews (1954) and Mack (1964) particularly with reference to the hot, burning sension of which some patients complain. Osteoporosis producing alteration in the alveolar ridge, and endocrine imbalance affecting the mucosa, are possible explanations of the coincidence of the menopause and denture discomfort. However, emotional upsets related to the menopause may be connected with the denture discomfort also. The increase of tension common at this period of a woman's life is one example of a stress situation in which a habit of non-functional tooth-clenching may occur, with consequent increased load on denture-bearing tissues.

VII.

Treatment of Failure of Support.

Failure of support of full dentures occurs when resistance to the vertical loads transmitted from the teeth involves intolerable discomfort or serious deterioration in the health of the tissues.

Treatment may be directed towards:

1. refining the prosthetic technique to avoid irritation of the mucosa by the dentures.
2. rectifying deficiencies of the denture-bearing tissues.
3. promoting the formation of an adequate denture foundation as a prophylactic measure.
4. ensuring a wide and even distribution of the load.
5. reducing the load when it is found to be excessive.

Prosthetic technique.

Denture bases which do not fit accurately may cause irritation due to localised "pressure spots" or due to abrasion of the mucosa by movement of the dentures.

Although retention may be maintained by favourable shape of the ridges and assistance by the musculature of the cheeks and tongue, an ill-fitting denture may still injure the underlying tissues. Similarly, instability due to occlusal imbalance may be compensated in function by a co-operative patient, but prove intolerable to the mucosa. Imperfections on the surfaces of models reproduced on the fitting surface of dentures during the moulding of acrylic can confer an abrasive potential to a baseplate, and even the faithful reproduction of crevices between rugae or folds of unattached mucosa may result in sharp projections on dentures which injure the soft tissues.

The provision of dentures with accurately-fitting bases free from irritating surfaces, and providing suitable relief in hard areas, is a primary requisite in treatment. The occlusion should be arranged to promote stability of the dentures in function, conforming to lateral and protrusive movements of the mandible while maintaining balance. The contribution of a precise prosthetic technique to the management of support problems was illustrated in the following special circumstances.

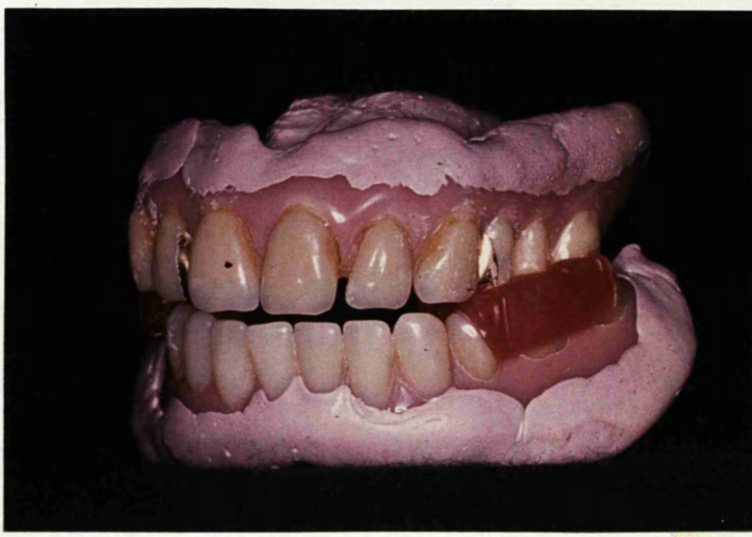
The introduction of the National Health Service in Britain produced an influx in general practice of patients requesting replacement of very old dentures. Due to long continued resorption of alveolar bone the denture bases no longer fitted and the height of the face had become greatly reduced. Often the dentures were in process of disintegrating, which, in many cases, was the main reason for the patient seeking help. Frequently, however, the new dentures proved less comfortable than the old ones and patients failed to tolerate their use. The sudden change in the shape and bulk of the appliances was thought to be outwith the power of accommodation of these older patients, and some practitioners favoured a process of gradually restoring the facial height by fitting a series of dentures over a period of many months. Others tried to avoid the difficulty by merely relining the old dentures. The basi c trouble in these cases was a failure of support.

A technique which of ten achieved tolerance of a complete restoration of vertical height in one step was introduced by the author at that time to deal with this problem. (Thomson, 1952). Impressions were obtained by a wash of impression paste in the old dentures, and jaw relationships were recorded by wax wafers inserted between the teeth of the old dentures after the paste had set. (Fig. 35). Impressions and "bite" in the old dentures were transferred to an articulator and new dentures made, having regard to the arch size and tongue space to which the patient had been accustomed, which the old denture showed.

The use of this technique resulted in satisfactory accommodation to new dentures (and tolerance of considerable increase in vertical height within physiological limits) in cases where the same operator might have expected failure if a conventional technique had been used.

The advantage seemed to be due mainly to the greater precision which could be achieved. Slight inaccuracy of impressions and in registration of occlusion, which may pass unnoticed in routine prosthetic practice, is less readily tolerated in these more exacting cases. In these cases,

FIGURE 35.



Impressions and centric relation as
recorded in the patient's old dentures.

however, inaccuracy is more likely to occur. Impression - taking is more difficult when the boundaries of the impression area are ill-defined, and the use of a wash impression in the old dentures facilitates the process. Bite blocks are insecurely located on the flat ridges and may easily be displaced when the occlusion is recorded. The paste-lined dentures provide a very stable base in these circumstances. In addition, the use of the familiar shape of the patients' own dentures reduces the difficulties involved in registering jaw relationships for older patients, which have been discussed by Liddelow (1964). So errors of the denture fitting surface and of the occlusion are more easily avoided, and any increased load which the new dentures place on the tissues is more readily tolerated.

It has been suggested that the form of the fitting surface of a new full lower denture should be a duplicate of the old one, even in cases in which there has been considerable change in the shape of the alveolar ridge since the old dentures were made. Berry and Wilkie (1964) commend this method, explaining its success by postulating that the crest of the lower alveolar ridge may have become inadequate for load-bearing over the years, whereas the tissues on which the peripheries of the flanges have been resting have become adapted to load-bearing.

Deficiencies of the denture-bearing tissues.

The crest of the alveolar ridge may be intolerant to pressure in cases which have suffered much loss of alveolar bone. A cortical layer may be absent, and sharp spicules of bone cause discomfort when a denture base sandwiches the mucosa between itself and the rough bone surfaces. Simple surgical intervention is indicated in these cases. In the same category are residual foci of infection, retained root fragments and protruding nodules of bone which may be relics of chronic sepsis or sclerosis associated with hyperfunction of isolated natural teeth in the past. Cautious surgical measures are useful in these cases, but a too radical approach may result in complete loss of an already insufficient alveolar ridge. An alternative method of treatment is to provide suitable relief on the fitting surfaces of the baseplates.

Inflammatory conditions of the mucous membrane may be resolved by suitable therapy. The hygiene of dentures may, in some cases, be inadequate, and constitue a continuing source of infection. The use of immersion-type denture cleansers containing sodium hypochlorite, when accompanied by suitable physical cleansing of the dentures and the use of a mildly antiseptic mouthwash, frequently suffices. It may be necessary to prohibit wearing of the denture until acute inflammation subsides, or to replace a very old or porous plate. Chronic inflammatory reactions resulting in hyperplasia may call for surgical removal of superfluous tissue. Cooper (1964), however, reported on the treatment of a series of cases of denture hyperplasia and advocated a conservative approach. He considered that denture hyperplasia occurs because folds of tissue from the sulcus become trapped within spaces beneath the bases of ill-fitting dentures, and the condition is reversible if the offending space is eliminated. So loss of sulcus depth, which may be a result of surgical intervention, can be avoided.

Soft tissues of the denture-bearing area which have suffered alteration of shape following prolonged use of ill-fitting dentures may recover to some extent if relieved of stress. Lytle (1957) demonstrated that alveolar ridge contour does in fact alter when traumatic loading is eliminated, and Boos (1959) recognised the need to allow tissue recovery by discarding old dentures for a short period before impression for new dentures were made.

Berry (1963) described marked improvement in the condition of inflamed and flabby tissues in the edentulous lower jaw following a treatment consisting of several consecutive applications of tissue conditioning materials as a denture lining. Heath (1966) considered the use of tissue conditioners to be a method of eliminating gross stress without depriving the patient of the use of dentures, providing also an immediate improvement of comfort and retention. Wilson and Osborne (1966) investigated physical properties of several materials recommended as both tissue conditioners and functional impression materials, and concluded that no one material is suitable for both purposes. A functional impression material should flow, whereas a tissue conditioner should be soft and resilient to effect a more even distribution of the load and allow recovery of deformed tissues.

So repeated applications of such materials to conform to the changing shape of tissues during recovery is the ideal method of using tissue conditioners, and is useful in cases where deterioration has not advanced to a state of break-down of the epithelium and acute or sub-acute inflammation.

The treatment of "denture sore mouth" usually requires the removal of the old dentures to allow relief from denture trauma and resolution of the active inflammatory reaction. Turrell (1966) considered the provision of satisfactory new dentures to be sufficient treatment, except in cases of monilial infection following antibiotic therapy, when additional measures to control the infection would be required. Nystatin (tabs. 500,000 units) dissolved in the mouth thrice daily for two weeks usually clears the infection of the mucosa. Re-infection from the old denture must be avoided if it is not replaced by a new one. Hypochlorite denture cleansers are again useful.

Promoting the formation of an adequate denture foundation.

Conservation of the alveolar bone and attached mucosa is undoubtedly important in preventing subsequent failure of support of full dentures.

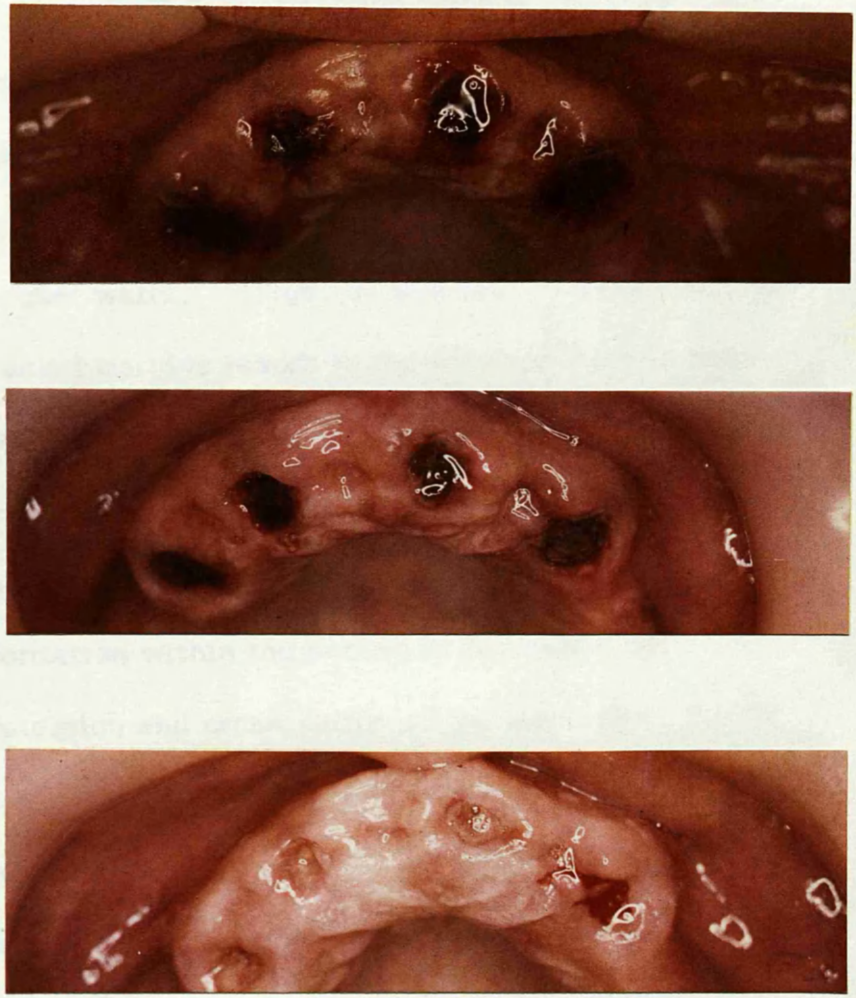
In deciding when to advise removal of teeth where there is evidence of progressive deterioration of the paradontal tissues, there is a responsibility for the dental surgeon to weigh the advantages of a limited period of retention of the natural teeth against the loss of useful denture foundation which continued retention of natural teeth might involve. A very conservative attitude to the natural teeth may involve inordinate expense of the bone which would form the residual ridge, and the expectation of the denture-wearing life is often much greater than the useful time which the natural teeth may be expected to serve. Although it may be possible, therefore, to delay the loss of natural teeth by periodontal treatment, in cases where progressive bone loss cannot be halted completely the prognosis must be assessed with the future prosthetic situation in mind. It may be wise in some cases to remove natural teeth before their paradontal condition demands extraction, in order to ensure reasonable conservation of alveolar bone.

Conservation of the residual ridges can be pursued after the decision to remove teeth had been taken. The process of tooth extraction should avoid unnecessary bone loss, and measures to promote satisfactory wound healing contribute fur ther to conservation of alveolar bone. Immediate denture service can make an important contribution to the management of extraction wounds (Thomson, 1958).

Initial healing of tooth sockets is influenced by the protection afforded by the baseplates of immediate dentures. (Fig. 36). The blood clot, unless protected, is liable to disturbance by food and saliva and by the explorations of the patient's tongue.

Experience in the management of extraction of teeth for haemophilic children demonstrates the value of adequate protection of extraction wounds. (Dennison and Thomson, 1958). In haemophilia the reduction of the increased clotting time which the haematologist can achieve is necessarily limited, and conservation of the rather fragile blood clot, once it is formed, is an important function of the dentist who is involved in such a case. Wound coverage by acrylic resin splints is now an accepted method of control, but its success was found to be dependent upon achieving satisfactory retention and stability of the splint. A satisfactory immediate denture

FIGURE 36.



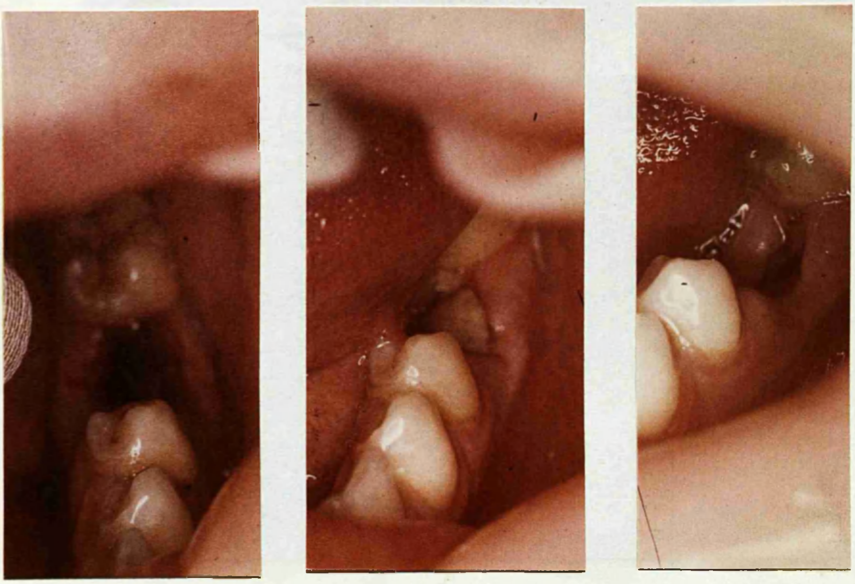
Extraction wounds suitably protected by an immediate denture showing progress of healing on the second, fifth, and twelth days.

serves a similar protective function for extraction wounds in normal cases.

In unprotected extraction wounds, varying amounts of the surface layer of blood clot is usually lost, and when epithelium seals the orifice a concavity is left between the plates of bone of the socket walls. (Figs. 37 and 38). Eventually the socket margins resorb to the level of the new bone which grows in the part of the socket which the blood clot occupied, with considerable reduction of the height of the remaining alveolar ridge. New bone formation within the socket is dependent upon the retention and organisation of the blood clot, so the loss of a portion of the clot leads to a loss of alveolar ridge. Conservation of blood clot, therefore, which the protection of an immediate denture affords, leads to formation of more bone and a better ridge.

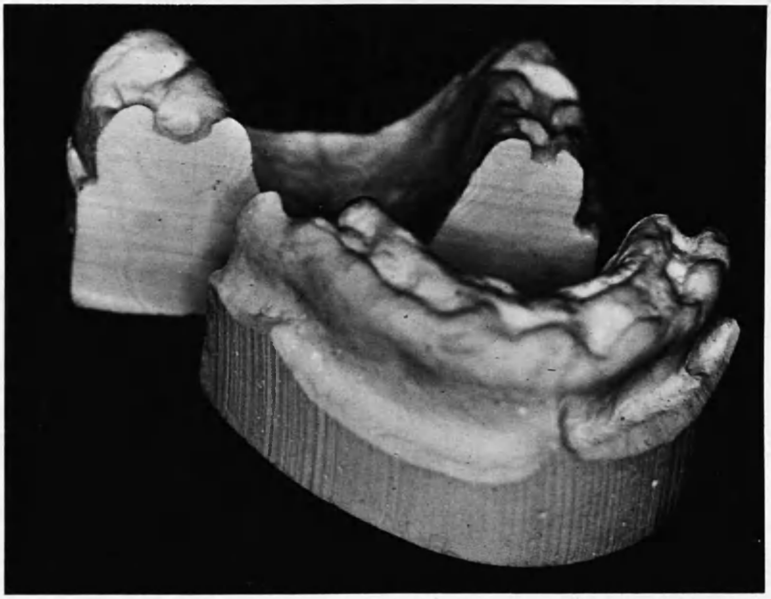
Much of the benefit may be lost, however, if the immediate denture is made with projections of acrylic entering the sockets, since the parts occupied by acrylic cannot contain blood clot to act as a scaffold

FIGURE 37.



Unprotected extraction wound as seen on the second, fifth, and twelfth days, with loss of blood clot and consequent concavity on the surface of the ridge.

FIGURE 38.

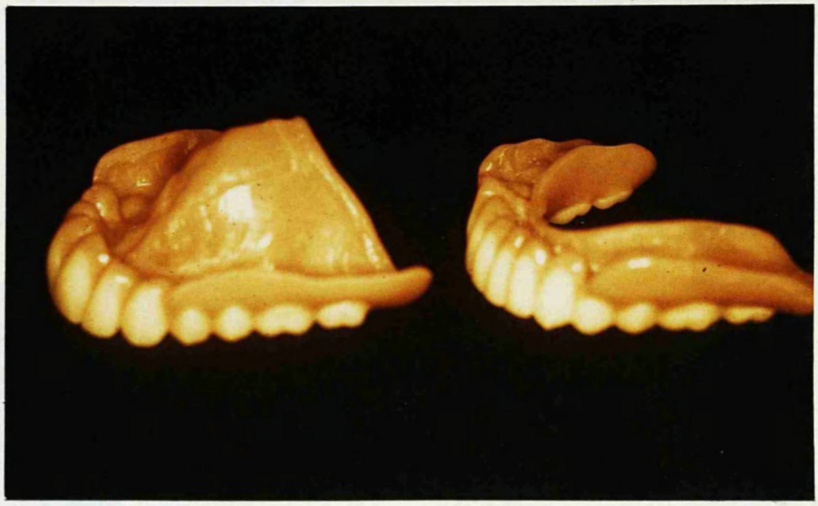


Models sectioned to demonstrate concavity between buccal and lingual bone of alveolar ridge, following loss of blood clot.

for bone formation. (Figs.39 and 40). So the ridge form eventually shows a series of depressions, bounded by hard bone margins. Apparently this method is adopted with a view to securing a closer fit of the denture bases for a longer time, but it would seem to be wiser to anticipate an earlier rebasing of the dentures, should this prove necessary, and so gain a more favourable denture foundation. Indeed in most cases the author favours the provision of labial flanges on immediate dentures, instead of the gum-fitted designs formerly used, to provide more complete protection for the extraction wounds.

To retain the initial benefit of the more complete resolution of the wounds and more favourable ridge formation, immediate dentures must be serviced to ensure that they remain stable. The satisfactory early accommodation of the facial and lingual musculature, which contributes much to the success of immediate denture prosthetics, of ten assists the patient to maintain control of the dentures after the baseplates have become

FIGURE 39.



Immediate dentures with projections
of acrylic entering the tooth sockets
and preventing satisfactory resolution.

FIGURE 40.

Injudicious deep "socketing" of anterior teeth of an immediate denture, resulting in an unsatisfactory residual alveolar ridge.

ill-fitting. (Figs. 41 and 42). Often the patient who reports with satisfaction that the immediate dentures remained comfortable for a long time presents alveolar ridges irregularly and grossly resorbed as a consequence. Continued servicing of immediate dentures during the period of active re-shaping of the alveolar ridges contributes to the formation of a satisfactory denture foundation.

Similarly, the maintenance of sufficient and satisfactory ridges can be jeopardised by unsatisfactory "permanent" prostheses. One feels that deterioration of some lower ridges may be due, in part at least, to unwise provision of dentures made to an excessive registration of vertical dimension, this being often an attempt to satisfy the patient's demand for aesthetic improvement. The collection of discarded dentures, which the "flat lower" subject may display, provides evidence of this tendency. The tissues react to overloading by resorption of bone until an interocclusal space is provided, and the denture foundation suffers

FIGURE 41.

An immediate denture apparently still fitting well after four weeks (above), but lack of fit can be demonstrated on digital examination (below).

FIGURE 42.

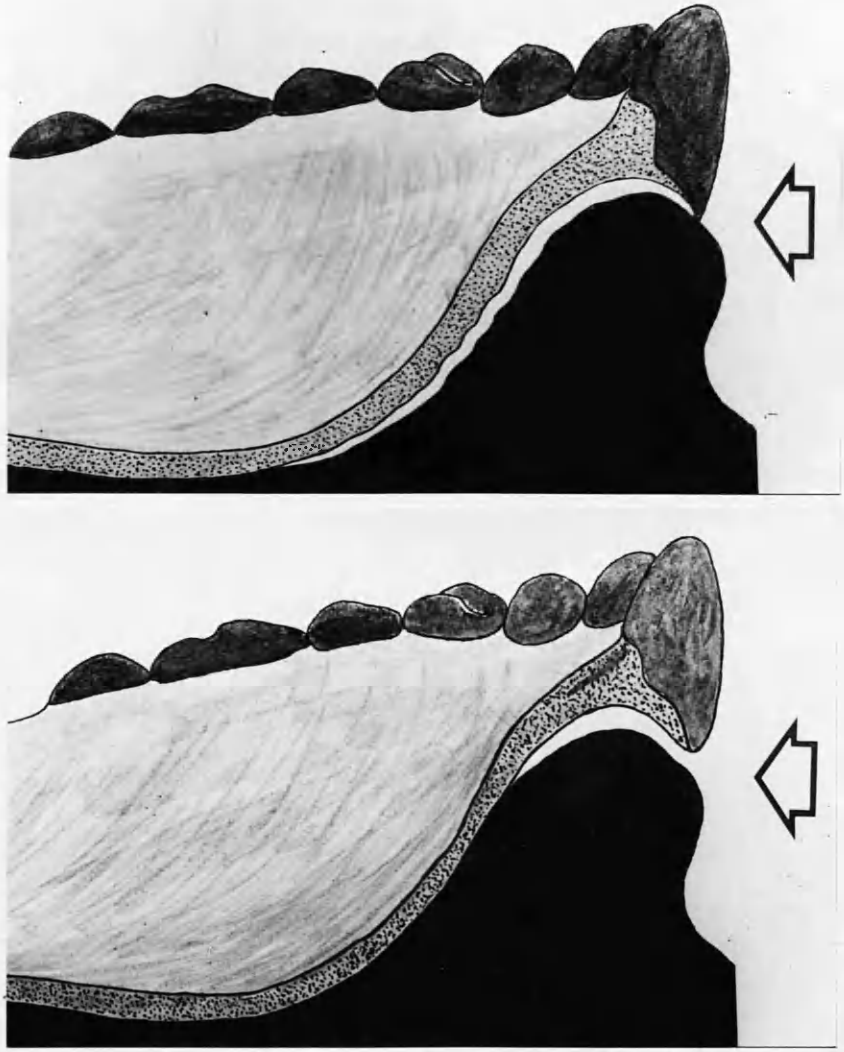


Diagram to explain the appearances in the previous photographs.

in the process.

The notorious "flat lower" demonstrates several factors which contribute to denture intolerance, namely - thin mucosa free to move over the bone, the fitting surface of the denture base reproducing folds in the mucosa as sharp projections, rough bone surface on the crest of the alveolar ridge following gross resorption, and lateral movement of the denture unchecked because deep flanges cannot be provided. The reduced denture-bearing area available in these circumstances produces a problem of support which may remain even after retention and stability have been achieved.

Reducing the effect of the load.

When the denture-bearing tissues are inadequate for the support of the load imposed, attention may be directed to the possibility of modifying the conditions of loading which prevail.

If the load is unevenly distributed over the available support areas, intolerance may result. Inaccurate registration of jaw relations will cause unequal loading, and unsuitable placing of the teeth relative to the alveolar ridges will cause imbalance. Similarly, incorrect relation of the opposing teeth to one another, insufficient incisal overjet and locked posterior teeth, invites excessive loading of certain areas, usually the anterior part of the lower ridge and the buccal flange areas in the posterior parts of the mouth.

Unequal thickness of the soft tissues covering different parts of the denture-bearing areas may require compensation, especially over the bony protuberances seen during the early stages of alveolar ridge resorption following the removal of teeth, or in the special circumstances of cases of torus palatinus and torus mandibularis. Provision of suitable relief for these areas in the baseplate avoids faulty load distribution causing discomfort.

Pendleton (1932) recognised primary and secondary stress-bearing areas and relief areas in the maxillary denture foundation, related to the suitability of the soft tissues for load-bearing. The primary stress-bearing area has a layer of dense fibrous tissue covering the bone of the alveolar ridge, and the relief area has a thin layer of tissue covering the suture in the median line of the palate. Based upon this observation are the impression techniques which aim to induce suitable degrees of compression of the areas of the denture-bearing soft tissues which yield more easily, in an attempt to achieve a more even distribution of the load.

The effect of the total load upon the tissues is reduced if the whole of the available denture-bearing surface of the mouth is utilised, so ensuring the widest possible distribution. Too of ten repeated "easing" of dentures, in response to patients' complaints of painful areas of mucosa, reduces tissue coverage in circumstances where further extension of the baseplates would be more appropriate. Recognition of failure of support as a frequent cause of continued discomfort would avoid this error.

Although the extension of full denture bases to utilise the whole available denture-bearing area is an accepted principle, inadequate impression technique often prevents achievement of this aim. Especially in the mandible, there may be scope for considerable addition to the base area, and this can effect a reduction of the pressure per unit area sufficient to relieve intolerance in an adequate support situation. In the case illustrated in Figure 43, the vertical support area at the full lower denture was increased from 1.49 squ.in. to 2.08 squ. in.

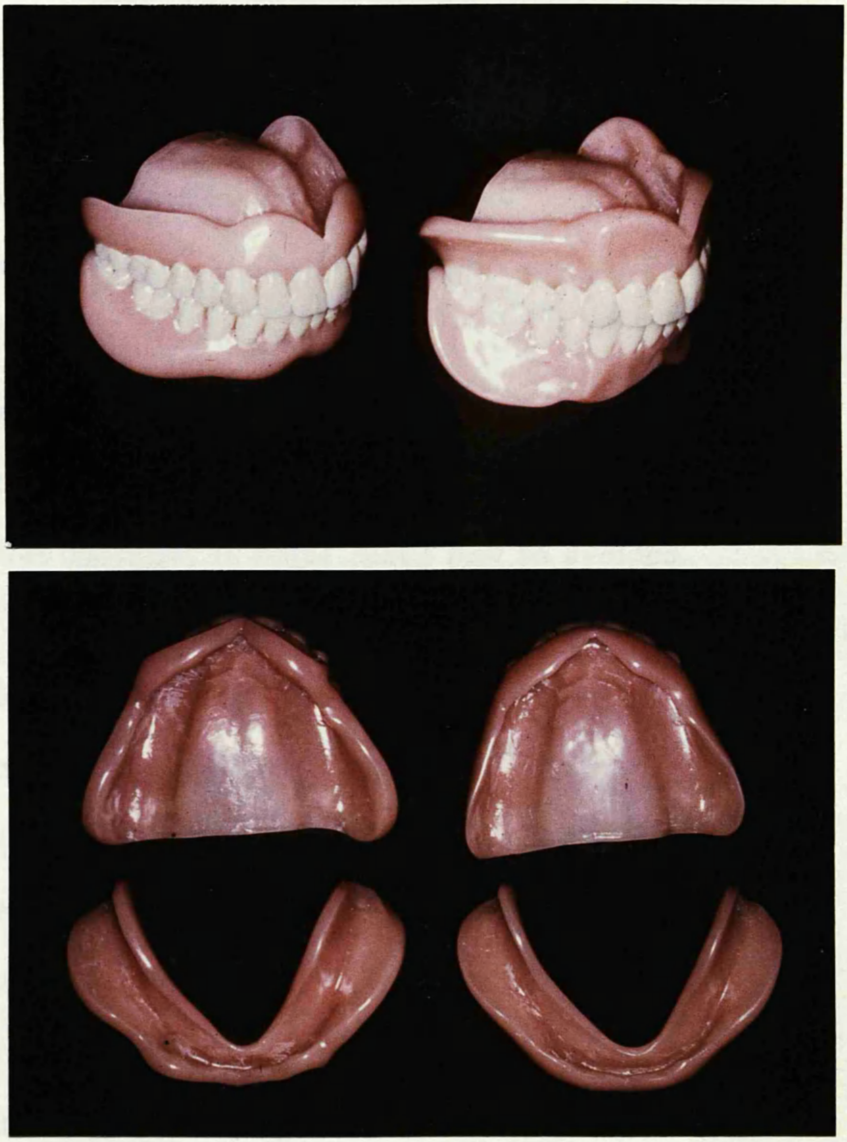
Dentures designed so that the facial and lingual surfaces present contours conducive to retention through the co-operation of the adjacent muscles tend to have broader peripheries and take advantage of any support which may be afforded by the tissues of the sulci. Fig. 44 compares dentures made for the same month which differ only in the design of the polished surfaces.

A more even distribution of the load upon the tissues is assisted by the use of resilient denture lining materials. Soft linings may serve to supplement

FIGURE 43.

Extension of full lower denture base to utilise the whole available area (below) compared to previous denture (unsuccessful) made for the same patient. (above).

FIGURE 44.



Dentures identical in arch form, demonstrating differing contour of facial surfaces and use of full width of sulci.

an insufficient thickness of mucosa which provides too little padding between the hard surfaces of the alveolar bone and the acrylic denture base. This circumstance arises most frequently in the atrophic denture-bearing tissues of older patients. Resilient lining materials may also be used to provide relief for hard areas in the mid-line of the palate or over prominent mylohyoid ridges. By this means the loss of retention which frequently accompanies the use of relief chambers in these cases may be avoided.

Lammie and Storer (1958) reported on a trial involving 109 patients for whom dentures with soft linings were fitted because of pain affecting the lower alveolar ridge. 91 reported improvement. The authors stressed that the mere addition of soft linings does not compensate for inadequate prosthetic technique, and so due attention must be paid to such factors as suitable extension of the denture base and balanced occlusion.

The application of soft linings is restricted to some extent by the limitations of the resilient materials available. Properties demanded of these materials for this purpose include ease of manipulation, adequate bonding to denture base materials, low water absorption for reasons of hygiene, absence of toxicity and permanence of resilience and dimensional stability. Several resilient plastics which have been used for soft linings suffer disadvantages. Polyvinyl chloride requires critical control of manipulation, polyvinyl acetate has a high water absorption rate, and methyl methacrylate copolymers have low abrasion resistance and a tendency to impermanence. The silicone materials seem to satisfy most of the requirements, but problems of bonding the lining to the denture remain, and mechanical attachment is required.

The incorporation of a shock-absorbing system analogous to that of the natural dentition has long been contemplated by prosthetists who are conscious of the relatively inferior support mechanism available for full dentures. The sandwich type of denture described by Ritchie (1963) is an attempt to realise this in practice by introducing a layer of resilient material within the base of the lower denture. In two long established cases of denture intolerance in which this technique was used by the author immediate success was achieved. After a year, however, when the resilient material had deteriorated, new dentures of normal construction were substituted without loss of comfort to the patients. One was doubtful, therefore, whether the resilient sandwich has contributed more than an opportunity for adaption or an unjustified confidence to the patients, or whether, in fact, other modifications to the design of the previous unsatisfactory dentures were the relevant factors.

The relief of the mucosa from load-bearing by the use of sub-periosteal implants remains as an additional possibility. This procedure must be regarded as outwith the range of the normal full denture techniques now practised, but the usefulness of its application as an ultimate answer to certain problems is recognised by those especially experienced and informed in this field.

In the concluding section of a series of papers covering full denture technique (Mack, 1964), this is made clear in the comment:

> "Perhaps the most decided advantage of a sub-periosteal implant is the fact that the fitting of such an appliance enables the patient to enjoy good function and comfort when all other procedures have failed. Provided their use is restricted to such cases, there appears to be every justification for their continued use".

Reducing the load.

Efforts may be directed to reducing the load which the teeth receive.

Care in ensuring that a freeway space exists when the mandible is in rest position is an absolute essential in technique to avoid continued overloading of the tissues.

Methods of assessing an appropriate vertical dimension for the occlusion in edentulous patients have been a subject of comment in the preceding chapter. In order to ensure the provision of a free-way space in cases where overloading of the tissues is suspected or anticipated, one would tend to err towards overclosure of the bite. However, it is necessary to avoid gross overclosure, one of the consequencies of which is a tendency to a forward posturing of the mandible. This may lead to occlusal imbalance and instability, and so be a cause of irritation of the denture - bearing mucosa.

Reduction of the area of the occlusal table provided by the posterior teeth is a way of reducing the potential load on the teeth during mastication. This is usually achieved by making the lower posterior teeth narrower bucco-lingually than normal. Thus a lesser bolus of food is involved in each chewing stroke, crushing of the food by a smaller occlusal area requires less total force, and the load on the mucosa is reduced.

Non-functional occlusion of the teeth has been suggested as a source of additional stress. When diagnosed as a factor which aggravates the tissues beyond the limit of their tolerance, elimination of the responsible habits is a useful aim in treatment.

<u>Treatment of tooth-occluding habits.</u>

Local causes of discomfort which may initiate tooth-clenching habits must be eliminated. The unaccustomed, sometimes excessive, bulk of new dentures in the mouth may stimulate activity of the muscles, which can continue as a habit after the initial discomfort disappears. Inadequate retention, possibly due simply to overextended buccal flanges, may cause the patient to occlude the teeth frequently to reseat the displaced denture, and this may provoke a habitual occluding of the teeth which persists even after satisfactory retention has been provided. Imperfections in occlusal relationships provide another stimulus to grinding and clenching reactions. Because these slight and temporary irritations may induce persistent and troublesome side-effects, early relief by adjustment of the dentures assumes greater importance.

Habits associated with the presence of foreign bodies in the mouth - chewing pencils, holding a pipe - are easily recognised by the patient as a cause of discomfort, and a solution can be agreed on this basis.

Stress-motivated habits, when forceful occlusal contacts occur during intense concentration in work or sport, or during periods of anxiety, physical effort or pain, are less surely eliminated. It may be necessary for the patient's personal attitude to life to change before he becomes a suitable subject for full denture prosthesis, or relaxation therapy may be achieved by deliberate effort by the patient himself, by suggestion or auto-suggestion, or by drugs, if these measures seem to be justified by the circumstances. It is often possible to identify a situation associated with tension and tooth-clenching. The patient's occupation is a useful subject for preliminary enquiry. Cases in one's own experience have been found to be directly associated with the performance of work such as steel erection, metal casting, transport driving, cash accounting, personnel management and sales promotion. Difficult domestic situations, anxiety during illness and bereavement have been disclosed as causes of tension, or the relevance of such circumstances have been made apparent although the patient was not prepared to admit them to discussion. Such situations may not be readily resolved, but if the patient becomes conscious of their relationship to his tooth-clenching habit there is a possibility of the habit being rejected. Merely to inform the patient of the relevance of his habit to his denture discomfort has been found to be sufficient to produce improvement in several of such cases, although the possibility of another habit replacing the one rejected has been noted.

A psychiatrist who was advised to rid himself of a habit of grinding the teeth of his denture together returned to report his success, but his mode of treatment involved holding an empty pipe securely clamped between his teeth - a system of sublimation which seemed to invite further dental discomfort.

The principle of auto-suggestion was recommended by Peterson and Dunkin (1955) who instructed patients to concentrate of the idea " I will catch myself if I bite or clench my teeth" to induce awareness of the habit. This was extended to deal with habits during sleep by use of the suggestion "I will awaken if I bite or clench my teeth". This is, fortunately, unnecessary in treating full denture subjects since the removal of the dentures at night would seem to be a more acceptable method.

The author has found that an explanation of the existence and importance of the free-way space in the rest position of the mandible is a useful approach to treatment. Patients are interested in the information that there should be a space between their teeth in the normal relaxed posture, and their essential co-operation is so secured. They are invited to try to note now and again each day whether in fact their teeth are apart. If the opposing teeth are found to be in contact, it is explained, something is wrong, and the jaw should be allowed to relax. In this way patients discover their habit, and accept their responsibility for the consequences. So impressed, they are motivated to try to correct their error. The explanation, presented in this way, is demonstrated to be reasonable and is accepted, and the advice of take positive action - to relax the jaw - is more satisfactory than an unexplained prohibition on clenching and grinding the teeth.

Moreover, the identification of tooth-occluding habits, the recognition of their role in causing failure of support of full dentures, and treatment directed to their eradication is more satisfactory in appropriate cases than the repeated exhortations to persevere in the face of difficulty which the denture-intolerant patient may receive.

When all the other causes have been eliminated, there will remain a few cases of denture intolerance in which true neurosis is the basic factor. Too often, perhaps, the patient who persistently complains of denture discomfort is labelled "neurotic" by the exasperated dental practitioner, the diagnosis being based only upon the absence of any other observed cause for intolerance of a denture. Neurosis may lead to a hyper-critical attitude to retention, stability, and aesthetics, and to a failure to adapt to the idea of wearing dentures and accepting their limitations: or it may lead to frequent muscular activity and repeated occlusion of the teeth which loads the denture-bearing tissues beyond the limit of their tolerance . Recognition of this latter condition provides, at least, a satisfactory physical explanation of the denture difficulties. The progress of any true neurosis present will be the governing factor, however, and the logical treatment is psychotherapeutic. The most useful contribution of the dental practitioner in these cases is to advise restricted use of the dentures until the general condition is resolved.

VIII.

SUMMARY.

Since satisfactory retention and stability now permit the acceptance by full dentures of wider functions, the support of the load imposed upon the denture-bearing tissues assumes greater significance. A plea is made, therefore, for the recognition of support as an attribute equal in importance to retention and stability for the success of full dentures.

The tissues which receive the load from the teeth of full dentures are less suited for that purpose than the tissues which support natural teeth. The reaction of the denture-bearing tissues may be unfavourable under ill-fitting dentures, and there may be clinical and histological signs of tissue deterioration in these circumstances. Subjective symptoms may accompany these adverse reactions, but in many instances the comfort of the patient may be unimpaired and normal function may be maintained. On the other hand, pain and discomfort

leading to loss of function may occur in the absence of clinical signs. It would appear that individual variations in the load-bearing potential of the denture-bearing area, and the loads which are applied, are significant in this context.

The loads recorded during tests of biting power are limited by the tolerance of the subject and his tooth-supporting structures. Full denture wearers exhibit much smaller biting forces than subjects with natural teeth. Masticatory function demands much less than the maximum exertion of which the muscles of the jaws are capable, but the recording of loading of the tissues during normal masticatory function, and especially to take account of loading during habitual non-functional occlusion of the teeth, presents technical difficulties. Since the distribution of the load over the denture-bearing areas is not uniform, the pressure upon any given area cannot be deduced, but deviations from normal in the total loading imposed and in the area available for load-bearing will be reflected in the support which the tissues are required to provide.

A distinct pattern of attrition caused by persistent tooth-grinding and tooth-clenching habits was identified during examination of patients wearing acrylic full dentures and was frequently associated with pain and discomfort in the denture-bearing tissues.

Attrition of acrylic teeth was simulated under laboratory conditions, and it required the prolonged and vigorous application of loads, equivalent to those reported to be used during mastication, to produce attrition similar to that observed clinically. Hence attrition due to habits of clenching and grinding of the teeth is indicative of considerable extra loading having been imposed upon the denture-bearing tissues.

In a consideration of diagnosis, support failure is distinguished from other causes of denture discomfort. Especial note is made of cases in which discomfort leading to intolerance of dentures was not accompanied by any clinical signs in the tissues or by any change in the usual histological appearance of denture-bearing mucosa. These cases were caused by over-loading, due either to excessive vertical dimension of the occlusion or to persistent non-functional tooth-occluding habits. The diagnosis of these two precipitating causes is discussed.

In considering the treatment of failure of support of full dentures, preventive measures to promote conservation of alveolar bone and the maintenance of favourable residual alveolar ridges and healthy mucosa are advocated. Suitable prosthetic technique and the treatment of the defective denture foundation is considered . Methods of reducing the effect of the load on the tissues aim to distribute the load widely and evenly. Reduction of the total load when it is found to be excessive is a possible expedient, and the elimination of non-functional habits of occlusion is discussed. In these ways an acceptable balance may be achieved between the load which the dentures impose and the support which the tissues can comfortably provide.

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