

THE BIOPHYSIOLOGICAL ASPECTS OF FULL MAXILLARY
IMMEDIATE DENTURE INSERTION.



A CRITICAL REVIEW.

SUBMITTED IN SUPPORT OF CANDIDATURE FOR THE DEGREE
OF MASTER OF DENTAL SURGERY.

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CHAPTER I.

INTRODUCTION.

There has been an increasing interest and attention over the last thirty years directed to a phase of prosthetic dentistry - that is the service which may be rendered to a patient by the insertion of an immediate denture.

The advantages to be gained by a patient receiving such treatment have been uniformly mentioned by authors. The degree of satisfaction expressed by the patient and the results observed by the dentist have prompted a considerable volume of eulogistic literature.

However, there are certain observations, attendant to immediate denture insertion, which raise queries in the mind of the operator, namely:-

Why is there an apparent reduction in the degree of blood loss?

Why do the tissues at the tooth extraction sites appear to heal more rapidly, with a denture covering the area, than the normal extraction wound exposed to the oral environment?

Why does the alveolar process, when completely healed, appear to provide a more satisfactory ridge form, in size and shape, for the construction and wearing of dentures?

These are the questions which provide the subject matter of this review. By examination of the structure and function of bone

and consideration of the alveolar process as a plastic, actively metabolising organism during wound healing, it is anticipated that sound biophysiological evidence will provide the answers to the above questions.

Certain factors will obviously not favour the insertion of an immediate denture. These factors will be discussed where appropriate, either in relation to general bone considerations and wound healing, or as separate entities.

CONTRIBUTING FACTORS TO IMMEDIATE DENTURE DEVELOPMENT.

It is felt that there are many contributing factors to the development of immediate dentures, namely:-

- 1) Improvement of existing materials used in denture construction through research and the setting up of standard requirements.
- 2) Development of new materials with desirable properties for dental use.
- 3) Simplification of techniques as a result of 1) and 2) through knowledge of the properties of the materials used.
- 4) More satisfactory methods and materials for producing anaesthesia, both local and general.
- 5) Utilisation of X-ray.
- 6) Introduction of a wide range of antibiotics allowing an effective control of infection,

in conjunction with the principles of sound surgical management.

7) Steady increase in the socio-economic level of the community producing:-

- a) a need on the part of the patient for a prosthetic replacement which fulfils maximum aesthetic and functional requirements immediately on loss of the natural dentition.
- b) a satisfactory reward to the dentist providing this service both personally and financially.

DEFINITION - WHAT IS AN IMMEDIATE DENTURE?

Van der Ven²⁹³ clearly defined this subject when he stated:-

"Immediate full dentures are prostheses which are made before the remaining teeth are extracted and which are inserted immediately after the extractions."

Swenson²⁷⁴ continues:-

"This form of immediate insertion is used in fixed prostheses and partial denture prostheses as well as in the construction of complete dentures. This form of construction may be used with a single complete denture or with maxillary and mandibular complete dentures."

For the purposes of this review, discussion is restricted to the full maxillary immediate denture for the following reasons:-

- 1) It is the most common form of immediate replacement.
- 2) The biophysiological mechanism of tissue repair applies equally to full or partial maxillary or mandibular immediate replacement.

TEMPORARY NATURE OF AN IMMEDIATE DENTURE.

From the above definitions, it is necessary to appreciate the temporary nature of an immediate denture. The biophysiological process of repair following any surgical procedure is clearly demonstrated in the oral cavity with the subsequent tissue changes involved. Therefore, any prosthesis immediately inserted will be only of a transient nature, (Jordan¹²⁴).

Smith²⁶⁵

"All immediate dentures must be considered transitional. It is to be expected that tissue changes will occur in the foundation of dentures immediately inserted."

and Frahm⁸²

"I speak of it as a transient restoration ...
... bridges the gap while the physiological transformation in the osseous support for the restoration takes place."

have shown a full appreciation of this factor.

However, Atkinson¹¹ emphatically denies that the expression "temporary denture" should be used in connection with an immediate denture. He claims that attention to details of construction will ensure satisfactory results as far as fit, retention and length of service are concerned.

HISTORY OF DEVELOPMENT OF IMMEDIATE DENTURE PROCEDURES. 1853-1930.

In 1853 Willard³¹⁰ of Chelsea, Massachusetts, described a surgical reduction of the alveolar process of "from a fourth to three-eighths of an inch deep; By this process (the gums) sooner become hard and firm."

Dentures were not immediately inserted, but the surgical intervention may be considered as the fore-runner to the techniques of alveolotomy and alveolectomy to be subsequently discussed.

Rodrigues in 1861²³¹ is considered to have been among the earliest operators to have taken an impression before the extraction of the teeth, bored depressions in the model cast, fixed the artificial teeth in the depressions and thus constructed the denture.

Fox in 1864⁸⁰ read a paper advocating "paring of the alveolar bone and excision of prominent septa."

"Heroic treatment" described by Beers in 1876¹⁷ suggested "the ultimate victory obtained over Nature in modelling with a regular and even arch one of the best imitations of a horse-shoe behind human lips."

The surgical removal involved large portions of the transverse

processes or septa, also the outer and inner plates of the alveolus. By this procedure he claimed "that several month's absorption will make the case what otherwise it could not have been - one suitable for gum teeth."

Claude Martin¹⁶¹ of Lyons was responsible for the insertion of extremely complex prosthetic replacements involving partial and total resection of the maxillae or mandible during the period 1889-1911. The rubber appliances were inserted immediately following the extensive surgery.

Francisque Martin,¹⁶² in an address in 1904, describes his father's methods as having:-

"the great advantage of replacing at one the resected bony fragment by an apparatus of the same size and form, and capable of fulfilling the functional role of the resected part."

The possibility of infection is considered by emphasis on the importance of frequent washings under high pressure through tube holes in the appliances.

Hatch in 1901¹⁰⁷ and Young in 1908³¹⁴ both suggest reduction of abnormally large or protruding alveolar processes for aesthetic reasons.

Clifford in 1916⁴⁶ appreciated the accepted advantages of immediate denture construction. His method did not include any surgical intervention, merely tooth extraction. The dentures so constructed appear to have been most successful, particularly in relation to the materials available.

Karl Witzel in 1917³¹² carried out a procedure of "surgical

intervention on the alveolar process, and preparation of the mouth for the reception of an immediate substitute after the extraction of teeth." His procedure apparently involved half the height of the alveolus.

Lowery in 1921¹⁵⁵ suggests that posterior teeth should be extracted with a healing period before immediate denture construction and insertion. His suggestion that photographic equipment be available in the surgery for record purposes, was an advancement.

Gross, 1921,¹⁰⁰ describes an alveolectomy operation using a special file which he designed.

The problems which a prominent anterior alveolus created to both aesthetics and function was appreciated by Viverito in 1921.²⁹⁶

The objectives of surgical preparation, "anticipating the eventual absorption of the labio-buccal plate" were propounded by Molt in 1923.¹⁷¹ His procedures were unchanged in a subsequent paper in 1949.¹⁷²

Ruy1 in 1924²³⁸ deplores excessive surgical reduction of the alveolar process and claims that the more conservative approach, alveolotomy, was introduced by him in 1914.

Support to the conservative surgical approach is given by Kazanjiam, in 1924,¹²⁷ certain abnormal cases, to simplify the prosthodontist's problems, being excluded.

Nodine in 1925²⁰⁰ was enthusiastic about the surgical removal of teeth and preparation of the tissues for the reception of dentures.

In a well presented paper in 1926, Sears²⁴⁸ showed an appreciation of the "Physical limitations of alveolectomy, the limits of

osseous reduction beyond which the oral surgeon should not go ...
 ... with the thought of removing only the very minimum
 amount of supporting osseous tissue in order that the requirements
 of the case be met with from the prosthetic standpoint."

Ziele in 1926³¹⁵ was most impressed by the conservative type
 of alveolotomy advocated by Ruyl.²³⁸

A year later, 1927, House¹¹³ suggested "thoughtful conserva-
 tism; that is, the least loss of alveolar structure that is per-
 missible with the removal of all pathologic tissue, ... and the
 correct forming of the ridges for the best mechanical and esthetic
 results."

SUMMARY.

From the historical review, the evolution of immediate denture
 construction and insertion can be traced.

Originally, aesthetic requirements suggested that the patient
 could be fitted with an appliance without experiencing either a
 partly or fully edentulous period of healing following tooth loss.

Then, from observation of the inevitable tissue changes which
 follow tooth removal the idea occurred to some operators that,
 by surgical remodelling of the alveolar process at the time of
 extraction, the same result could be accomplished as normal re-
 sorptive processes.

The variables inherent with any surgical reduction of the al-
 veolar process were not, as yet, appreciated.

Finally, the results of too enthusiastic surgical procedures
 prompted a more conservative approach to the problem, exception
 being made for particular cases of gross alveolar prominence.

ADVANTAGES.GENERAL:

When a patient has reached the stage, at which further conservative treatment of the remaining natural teeth cannot be considered, then the decision must be made as to the advisability of immediate denture insertion. Alternatively, the patient may seek help for an aesthetically unpleasing appearance which causes him, or her, embarrassment.

The advantages of this service to both patient and operator are numerous, but must be carefully weighed against possible disadvantages, or contra-indications in the diagnosis, to achieve a satisfactory result.

The patient must be fully cognisant (89) of these factors before treatment starts, for the decision is his, and the responsibility jointly held with the operator.

The generally accepted advantages of immediate denture construction are considered in order to provide a complete appraisal of the subject.

PSYCHOLOGICAL:

The factor uniformly mentioned in the literature, is the great psychological advantage to the patient with immediate dentures, (89, 274, 188, 7, 119, 265, 268, 35, 248, 63, 104).

An edentulous period of healing, following tooth extraction, provides considerable embarrassment to the patient which can be proportionally related to his or her social and business commitments, (274, 188, 140, 131, 76). This may be of such importance to the

patient as to cause delay in effecting treatment, which may produce general ill-health from prolonged retention of infected teeth, (119, 274, 124).

By careful management, the transition from remaining natural teeth to immediate restoration may be so imperceptible as to remain unnoticed by family or business associates, (188, 104, 280).

AESTHETIC:

a) Reproduction of Natural Teeth.

As Swenson²⁷⁴ states, "the greatest art is to conceal art, and this is possible in immediate dentures by placing the teeth in their former identical positions." This allows reproduction of arch shape and size with each tooth correspondingly arranged, following the choice of the same type, size, form and colour of the natural teeth, (274, 89, 293, 152, 91, 7, 5, 268, 241, 275, 131).

Kelly¹²⁹ and Johnson¹²² have suggested using tooth acrylic processed in a mould duplicating precisely the natural tooth arrangement.

Van Victor^{291, 292} processes a mould of each natural tooth in tooth acrylic, which teeth he then inserts in the impression prior to pouring the stone cast. This allows modification to be made for function during the setting of the posterior teeth.

It may be considered necessary to modify the natural tooth

positions in constructing the dentures⁸⁹ but it is suggested that these changes should only be made with the consent of the patient²⁷⁴ and where the aesthetic or functional demands of the case warrant the alteration.⁹¹

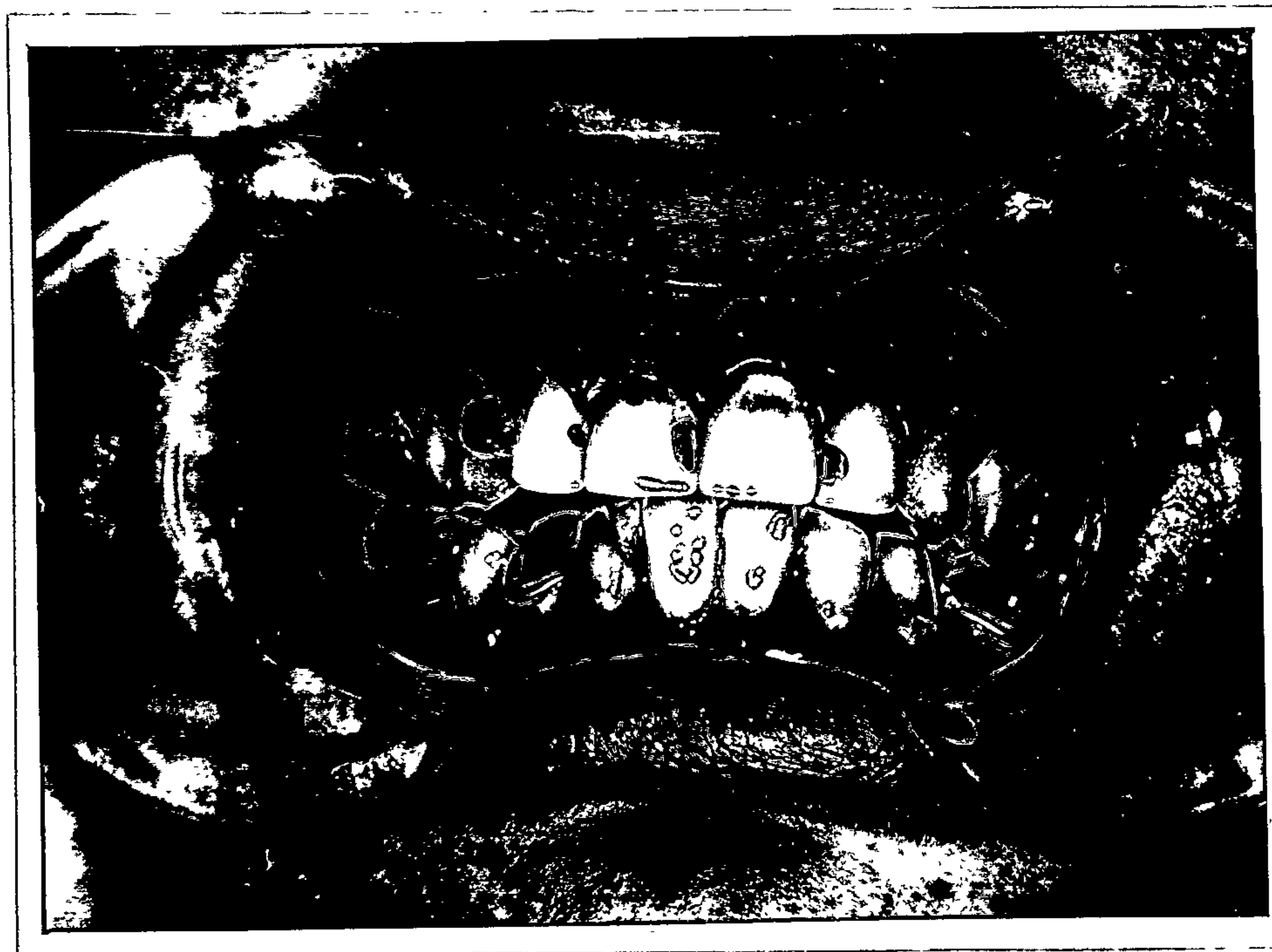
b) Maintenance of Vertical Dimension.

It has been generally agreed that the mandibular rest position is a constant throughout life (284, 285, 221, 29, 199) with a free-way space which varies from 2-10mms.²⁸⁴

However, more recent work by Tallgren²⁷⁷ shows pronounced changes in face height during the first year of wearing dentures, following tooth extraction, suggesting "a period of adaptation." These patients did not have immediate dentures inserted, but were edentulous for only a very short period.

Koivumaa¹³⁴ on a series of 333 partial denture wearers, produced results showing a great variation in mandibular rest position in individuals and groups at different developmental stages.

Clinically, however, the aesthetic effects of loss in vertical dimension are only too obvious in prosthetic practice (265, 119, 131, 5, 248, 274, 89, 7, 293) showing:-



Figs. 1 and 2. Aesthetic reproduction of natural teeth showing individual tooth characterisation and staining and contouring of the denture bases.

- i) Chin appears sharpened and too close to the nose.
- ii) Lips lose their fullness and the vermilion border is reduced to a minimum.
- iii) Corners of the mouth turn down with possible angular cheilitis.
- iv) The function of the muscles of expression, speech and mastication is impaired, with resultant loss of muscle tone producing sagging lines around the lower two-thirds of the face.

FUNCTION:

The patient, having arrived at the stage when full dentures are considered necessary, has experienced some degree of loss in masticatory efficiency from broken down and missing teeth, as shown by Manly.¹⁵⁸

The ability of denture wearers to masticate has been assessed by Thompson²⁸⁶ and Manly and Vinton,¹⁵⁹ the results of the latter proving that masticatory efficiency and denture standard are directly proportionate.

The transition from reduced efficiency of imperfect dentition to the wearing of an immediate denture appears to be accomplished with "greater ease, and less discomfort."⁸⁹ The initial period after denture insertion requires care in chewing,¹⁸⁸ but, following a period of adaptation, allows favourable function and ability, (89, 7, 188, 63, 293, 5, 265, 131).

PHONETICS:

The mechanism of speech is complex involving "the larynx, lungs, trachea, pharynx, the mouth with lips, tongue, teeth and the hard and soft palates, the resonant sinuses and the muscles of respiration."⁸⁹ However, it is the tongue which is principally responsible for producing the tones in articulate speech.⁸⁹

When the teeth are set duplicating the natural dentition, as in most instances of immediate dentures, then it is reasonable to expect the phonetic requirements to be satisfied. (89, 188, 63, 293, 265, 131).

This is subject to certain details also being faithfully executed, namely:-

1. Minimum thickness of the denture base.
2. Correct peripheral extensions.
3. Proper restoration of all palatal, lingual, labial and buccal ridge contours.⁸⁹

ACCURATE RECORDING OF VERTICAL DIMENSION AND CENTRIC RELATION.

It has been suggested^{35, 293, 119} that with the natural teeth standing, then the correct vertical dimension of the particular case may be accurately reproduced.^{57, 131}

However, with loss of teeth and particularly loss of posterior teeth, an alternative eccentric position of the mandible may develop. This is a more acceptable position to the patient and is found by a trial and error learning process.^{188, 140, 89} As stated by Osborne and Lammie:²⁰⁹

"This new position is reinforced as a main act and is perpetuated as a learned pattern in functional movements."

Associated with over-closure of the vertical dimension, labial migration of the upper anterior teeth and resultant diastema occurs.²⁰⁹ The only solution to this problem may be the insertion of an immediate denture to restore the vertical dimension.²¹⁰

CONTROL OF BLEEDING AND REDUCTION IN BLOOD LOSS.

Authors (35, 293, 310, 265, 104) generally agree that the insertion of an immediate denture "acts as a bandage and reduces the loss of blood."¹⁸⁸

Normal blood clot formation is not disturbed because the denture covers the extraction sites as a protective barrier or splint, (248, 293, 188, 82, 119, 7, 265, 57, 275, 131).

Trauma to the tissues and blood clot from food debris or tongue movements is prevented and consequently the possibility of infection is reduced, (248, 188, 274, 5, 82, 265).

Less pain and discomfort appear to favour the initial insertion of the denture, thought to be due to the splinting action of the denture, (188, 89, 274, 293, 119, 82, 75, 131).

RAPID HEALING OF TISSUES AND CONSERVATION OF RIDGE FORM.

It is generally observed that the rate of healing of the tissues at the tooth extraction sites under immediate dentures, is more rapid than when these sites are exposed to the oral environment, (7, 274, 188, 248). Presumably, the denture acts as a splint.

Kelly and Sievers¹³⁰ suggest also that the more rapid tissue healing is promoted by the stimulation provided by the denture base under function.

This functional stimulation appears to induce the formation of a smoothly rounded alveolar bony ridge with a thick mucosal covering, favourable to the satisfactory wearing of a denture by the patient, (293, 265, 188, 274, 268, 7).

The value of balanced occlusion, in relation to the forces exerted on the alveolar process during function, has been appreciated by Landa¹⁴⁰ and others.^{188, 89}

Some authors consider that the time interval, during which normal tissue resorption occurs, may be dispensed with by surgical reduction of the alveolar process coincident with immediate denture insertion, (17, 310, 5, 171, 312). It may be considered significant that more recent literature supports a conservative approach to surgical intervention, (124, 120, 81, 156, 53, 122, 245, 246, 247). However, where abnormal jaw or tooth relationships exist, surgical remoulding of the alveolar ridge is indicated and may prove of undoubted value to both patient and operator.²⁷⁰

CHAPTER II.CONSIDERATIONS OF THE ANATOMY, HISTOLOGY, BIOCHEMISTRY AND
PHYSIOLOGY OF BONE TISSUE.DEFINITION.

Bone is a hard, specialised form of connective tissue performing the primary function of skeletal support and the secondary function of serving as a store of calcium, (Maximow and Bloom¹⁶⁶).

The hardness of bone results from the deposition within a soft organic matrix, of a complex mineral substance composed chiefly of calcium, phosphate and carbonate, (McLean and Urist¹⁸⁵).

CONSTITUENTS OF BONE TISSUE.

As a living tissue, bone consists of two elements, permanent and transient.

The permanent element consists of specialised cells osteocytes, and their product, the intercellular substance.

The transient element consists of cells which are active during the formation and resorption of bone, osteoblasts and osteoclasts respectively, (Weinmann and Sicher³⁰⁰).

PERMANENT ELEMENT.OSTEOCYTES.

These cells of bone are osteoblasts which have become embedded within the calcified intercellular substance, (Maximow and Bloom¹⁶⁶,
McLean and Urist¹⁸⁰)

The cell body is oval and flat, rather like a plum stone in shape, with numerous branching processes extending in all directions. Many of these processes fuse with similar processes of the neighbouring cells to form a syncitium, (Weinmann and Sicher³⁰⁰).

Mitosis does not occur in mature osteocytes, however, differentiation from osteoblasts is sometimes difficult and mitotic division may be suggested in microscopic studies, (Weinmann and Sicher³⁰⁰).

Generally osteocytes show considerable variation in size, shape and intracellular detail, as well as in density of packing and regularity of arrangement within the matrix, according to their maturity and the kind of matrix with which they are associated, (Pritchard²²⁰).

INTERCELLULAR SUBSTANCE.

The intercellular substance is a calcified collagenous substance containing the osteocytes in lacunae and their processes in fine canaliculi, (Weinmann and Sicher³⁰⁰).

In addition to being calcified, the interstitial substance has a fibrillar structure similar to that of ordinary connective tissue, (McLean and Urist¹⁸⁰). However, special staining methods are necessary to reveal the fibrillar structure which is composed of bundles of collagen fibrils, varying in thickness 3-5microns.

It is the arrangement of these bundles of collagen fibrils, together with the ground substance, which forms the organic framework of bone, (McLean and Urist¹⁸⁰).

Lining the lacunae and canaliculi, the bone tissue is lacking in fibrils and although other parts of the intercellular substance are readily destroyed by alkalis, this lining layer is highly resistant. It is termed the capsule of the osteocyte, (Weinmann and Sicher³⁰⁰).

TRANSIENT ELEMENT.

OSTEOBLASTS.

These cells are responsible for the formation and calcification

of the intercellular substance of bone tissue, appearing on the surface of bone which is undergoing growth and development, (Weinmann and Sicher,³⁰⁰ Maximow and Bloom,¹⁶⁶ McLean and Urist¹⁸⁰).

The size and shape of osteoblasts varies considerably, with some correlation to the rate of bone formation being observed. Where bone formation proceeds rapidly, the osteoblasts are of an irregular cuboidal shape arranged over the surface in a continuous layer, (Weinmann and Sicher³⁰⁰).

Intercellular bridges unite the osteoblasts and, during bone growth, these bridges lengthen considerably, developing into the branching and anastomosing processes of the osteocytes, (Weinmann and Sicher³⁰⁰).

Under the influence of the parathyroid hormone, the osteoblasts may engage in phagocytic activity, assume the form of osteoclasts and osteocytes and possibly play an active part in bone resorption, (McLean and Urist¹⁸⁰).

OSTEOCLASTS.

Osteoclasts are multinucleated giant cells, varying greatly in size, shape and number of nuclei, (Maximow and Bloom¹⁶⁶).

Maximow and Bloom,¹⁶⁶ and McLean and Urist¹⁸⁰ are of the opinion that osteoclasts are derived from:-

- 1) The stromal cells of the bone marrow.
- 2) The fusion of a number of osteoblasts.
- 3) The fusion of osteocytes liberated during bone resorption.

However, Weinmann and Sicher³⁰⁰ suggest that these derivations are unsubstantiated and that the origin of osteoclasts is by

differentiation from cells of the loose connective tissue, Maximow's undifferentiated mesenchymal cells or reticular cells. Certainly, the resorption of bone is always accompanied by proliferation of the adjacent connective tissue.

Osteoclasts are often found in more or less shallow grooves on the surface of the bone undergoing resorption. These grooves, which look as if they had been hollowed out by the osteoclast, are called Howship's lacunae, (Weinmann and Sicher³⁰⁰)

ARRANGEMENT OF THE ELEMENTS OF BONE.

GENERAL ARRANGEMENT.

Bone is laid down in thin layers of intercellular substance, 4-12 μ thick, giving a lamellated appearance with the cells of bone, osteocytes, spread out in the plane of the lamella, (Weinmann and Sicher³⁰⁰).

Some of the processes of the osteocytes perforate a lamella to communicate with adjacent or even further removed osteocytes. This fibril interlacing permits differentiation of the lamellae in sections, as for example where the fibrils are at right angles to each other, one lamella may appear striped and the other stippled. It is by means of the fibrillar arrangement that bone is able to resist mechanical forces, particularly shearing forces, (Weinmann and Sicher³⁰⁰).

In one localisation, however, bone is almost exclusively under tensile force, and that is in the innermost layer of the dental alveoli to which the suspensory fibres of the periodontal membrane are attached. Here the lamellae of the bone are indistinguishable as

the direction of the fibrils is not subject to a regular change from layer to layer, (Weinmann and Sicher³⁰⁰).

Macroscopically, two types of bone can be distinguished, spongy or cancellous bone and compact bone. The shape and arrangement of the lamellae constitute the difference, (Weinmann and Sicher³⁰⁰).

SPONGY BONE.

Spongy bone is simple in structure but varied in form, (Maximow and Bloom¹⁶⁶). It consists of bars, plates or tubules of bone of varying thickness and length and joined to a three-dimensional network, (Weinmann and Sicher³⁰⁰).

A few lamellae, generally arranged parallel to each other or in concentric layers closely connected with the distribution of the blood vessels which nourish the bone, constitute a trabecula, (Maximow and Bloom¹⁶⁶). In spongy bone, the spaces between the trabeculae communicate, (Weinmann and Sicher³⁰⁰).

COMPACT BONE.

The unit of structure of compact bone is the haversian system or osteon, (Maximow and Bloom¹⁶⁶, Weinmann and Sicher³⁰⁰, McLean and Urist¹⁸¹). Each system consists of a varying number of concentric lamellae, grouped around a narrow axial canal which contains blood vessels and a small amount of loose connective tissue, (Weinmann and Sicher³⁰⁰).

These concentrically arranged lamellae of bone may vary from 4-20 in number in a single system, each being 3-7 microns in thickness, (Maximow and Bloom¹⁶⁶).

The bone cells, osteocytes, of the haversian system are arranged

with their long axis parallel to the long axis of the system and their broad surface radially parallel to the lamellae. The processes of the osteocytes in the innermost lamellae open into the haversian canal via the canaliculi. Circulation of tissue fluid through the syncytium of the osteocytes and the intercellular substance is effected by this means, (Weinmann and Sicher³⁰⁰).

In the outermost lamellae, the processes rarely communicate, but loop back into the lacunae from which they arose, (Weinmann and Sicher³⁰⁰).

The different direction of the fibrils of each lamella can be distinguished crossing each other at acute angles, but maintaining a general direction of flow, (Weinmann and Sicher³⁰⁰).

The haversian canal carries one or two blood vessels which are mainly capillaries and post-capillary vessels lying in close association with the loose connective tissue filling the remainder of the canal, (Maximow and Bloom¹⁶⁶).

The connection between adjacent haversian systems is via short canals, Volkmann's canals, which also perforate the outer and inner layers of compact bone to allow communication between the vessels of the haversian systems and the vessels of the periosteum and bone marrow, (Maximow and Bloom¹⁶⁶).

Irregular spaces between the haversian systems are occupied by irregularly arranged lamellae, the interstitial lamellae. These are thought to develop from partly destroyed haversian systems or remnants of circumferential lamellae during the growth and reconstruction of the bone, (Weinmann and Sicher³⁰⁰).

STRUCTURE AND COMPOSITION OF BONE.

Since bone is a living tissue in dynamic equilibrium with the body fluids, its chemical constitution varies not only from one bone to another, but also within its microscopic structures, (Carlström and Engström³⁸).

BONE MATRIX.

The organic framework of bone varies for the type of bone, but in the compact bone of adults, constitutes approximately 35% of the dry, fat-free weight of which only a very small fraction is contributed by the cells.

The organic matrix of bone has two chief components, a collagenous fibrillar network and an amorphous ground substance, between which is found a fluid resembling that of other tissues, (McLean and Urist¹⁸²).

COLLAGEN.

Bone collagen is the substance in bone which yields glue or gelatin when boiled. It constitutes 90-96% of the dry fat-free weight of the organic matter, (McLean and Urist¹⁸²).

STRUCTURE.

Collagen fibres appear under optical microscopy as cords, bundles or ribbons of indefinite length and 20-200 microns in width. Further subdivision longitudinally of the fibres has been shown by electron-microscopy to allow differentiation into fibrils about 3-5 microns in width, (Rouiller²³⁴).

This fibrillar arrangement is characteristic of collagen with

double cross-banding at intervals averaging 640 angstrom units,
(McLean and Urist¹⁸², Rouiller²³⁴).

In young individuals or in bone of recent formation, the diameter of the collagen fibrils is less than in mature bone,
(Rouiller²³⁴).

CHEMICAL COMPOSITION.

Collagen is either a pure protein or a mixture of proteins with other substances.

It is poor in some of the amino acids essential to protein metabolism, (McLean and Urist¹⁸²) but unique in possessing a high proportion (13-14% by weight) of hydroxyproline; the only other protein to contain this amino acid is elastin, (1.5-2.0%), (Eastoe⁷⁴).

The molecular weight of collagen is very great, exceeding ten million, which makes chemical analysis of the amino acid sequence extremely complex, (Eastoe⁷⁴).

GROUND SUBSTANCE.

The ground substance together with the bone mineral and reticular fibres, occupies the spaces between the collagen fibres,
(McLean and Urist¹⁸²).

STRUCTURE.

The ground substance varies in consistency from that of the interstitial fluid to that of the basement membranes of the bone cells. The interconnection of the ground substance with the tissue fluid, permits the exchange of ions and other substances with the blood, (McLean and Urist¹⁸²).

CHEMICAL COMPOSITION.

The ground substance of bone has been assumed to be a protein-polysaccharide complex, with the mucopolysaccharides, hyaluronic acid and chondroitin sulphate as the characteristic constituents, (McLean and Urist¹⁸²).

The protein portion of the complex had been assumed to be degraded collagen, however, it is now thought that the protein is of entirely different composition, being a true mucoprotein in which the protein and carbohydrate fractions are firmly bound to form a macro-molecule, (Eastoe⁷⁴).

RETICULIN FIBRES.

The reticulin fibres are believed to occupy a position mid-way between the collagen and the mucopolysaccharides of the ground substance in structure and chemical composition. Under electronmicroscopy, these fibres show a periodic cross-banding similar to collagen, (McLean and Urist¹⁸², Eastoe⁷⁴).

However, a higher carbohydrate content is definitely present in the reticulin fibres with more active surface phenomena being exhibited - surface/volume ratio, relation of surface to ground substance etc., -(Rouiller²³⁴).

BONE MINERAL.

There is a considerable variation in the amount of mineral present in bone. For example, adult compact bone may contain 65% of mineral compared to 35% in developing or embryonic bone, measured for the dry fat-free weight, (Maximow and Bloom¹⁶⁶).

Certainly it is the mineral content which gives to bone the

property of hardness.

STRUCTURE.

The crystalline structure of the bone mineral has been subject to considerable controversy.

Neuman and Neuman¹⁹⁵ suggest that the most logical view at present is that bone mineral consists of microcrystals of hydroxy apatite. The composition of these crystals is determined largely by surface ionic exchange and to some unknown extent by internal defects and substitutions.

The microcrystals of bone mineral are extremely small, of the order of 200 by 30-70 angstrom units, which means that enormous surfaces are available for exchange substitutions of ions foreign to the hydroxy apatite lattice. These surface reactions render the bone mineral quite variable in composition and solubility, (Neuman and Neuman¹⁹⁵).

The suggested prototype for the hydroxy apatite crystal of bone is fluorapatite $[Ca_{10}(PO_4)_6 \cdot F_2]$, (Neuman and Neuman¹⁹⁵).

By inclusion of the impurities present in the fluids in which the crystals form, the over-all composition of average bone mineral, converted to mole ratios may be written as, (Neuman and Neuman¹⁹⁵)-

$$\left[Ca_9^{++} (H_3O^+)_2 (PO_4^{=})_6 (OH^-)_2 \right] \left[Ca^{++} \cdot Mg_{0.3}^{++} \cdot Na_{0.3}^{+} \cdot CO_3^{=} \cdot cit_{0.3}^{=} \right].$$

CHEMICAL COMPOSITION.

As may be seen from the above formula, the chemical composition of the bone salt consists of Ca^{++} , $PO_4^{=}$, OH^- , carbon dioxide, citrate and water with an admixture of small amounts of other ions, especially Na^+ , Mg^{++} and possibly K^+ , Cl^- and F^- , (McLean and Urist¹⁸³).

RELATION BETWEEN THE CHEMICAL AND STRUCTURAL COMPONENTS OF BONE.

Eastoe⁷⁴ has attempted to relate the chemical constituents of bone tissue to the structural elements, with the object of presenting a complete picture of bone structure.

His conclusions are summarised as follows:-

- 1) Inorganic matter in the form of crystallites account for 50% of the weight of bone.
- 2) The protein, collagen, is the second most abundant component of bone. Considered purely as a protein, it is clearly the main constituent of the banded fibrillar structure, although it frequently occurs in association with a variable quantity of mucopolysaccharide. This, however, is not an essential part of the macromolecule.

It is possible, however, that the mucopolysaccharides may form a type of cementing substance for the collagen fibrils by virtue of the electrostatic forces which operate between oppositely charged ionised groups.

- 3) Water is always found in bone tissue, accounting for at least 20% of the total weight. The diffusion of inorganic ions, sugars and other small organic molecules necessary for cell nutrition are mediated by its presence as is also the escape of waste products.

BODY FLUIDS IN RELATION TO BONE.

The particular body fluid in intimate contact with bone being unavailable for examination, studies have been directed towards blood serum with the assumption that any abnormality of the fluid in contact

with bone will be reflected in the serum, (Albright and Reifenstein,¹ Neuman and Neuman¹⁹⁴).

SERUM CALCIUM.

General Considerations.

The normal serum calcium value is 10.0mgs. per 100ccs. plus or minus 1mg. (Albright and Reifenstein¹).

This level is remarkably constant, the feeding of diets either high or moderately deficient in calcium does not alter it significantly (Jenkins¹²¹).

The threshold for calcium excretion in the urine is about 7.0mgs/100ccs. At this level a calcium intake of 0.05gms. would involve a constant drain of calcium from the body, (Albright and Reifenstein¹).

Since over 99% of the body calcium is contained in the bones and teeth, it follows that if the calcium output is greater than the intake, then the deficit will have to come from the bones, as the calcium turnover in adult teeth may be disregarded, (Albright and Reifenstein¹).

STATE OF CALCIUM IN SERUM.

Calcium in the serum is composed of three fractions, (Albright and Reifenstein¹):-

- 1) Calcium ions, 45%, (Jenkins¹²¹).
- 2) Calcium bound to protein - Neuman and Neuman¹⁹³

conclude that roughly three-fourths of the protein-bound calcium is carried by serum albumin under normal circumstances.

Keating¹²⁸ mentions that the calcium proteinate

is neither diffusible, ionisable and is apparently relatively inert.

- 3) Calcium in an almost negligible, diffusible but unionised fraction, 5%, (Jenkins¹²¹). This fraction is thought to be composed of a variety of substances such as calcium citrate, calcium salts of other organic acids and possibly colloidal tertiary calcium phosphates.

SERUM PHOSPHORUS.

General Considerations.

Phosphorus, like calcium, is found in large amounts in bones and teeth - in the ratio C : P = 2 : 1 - and in small amounts in blood serum, (Albright and Reifenshtein,¹ Keating¹²⁸).

The normal level in adult serum is 3.2mgms. plus or minus 0.5mg. per 100ccs.

Phosphorus differs from calcium in that relatively large amounts occur also in the cells of the body, not being confined to bone cells. The presence of phosphorus in body cells is necessary for many metabolic processes, (Keating¹²⁸).

STATE OF PHOSPHORUS IN SERUM.

The distribution of inorganic phosphate in serum is much less complicated than that of calcium. Protein binding is negligible and, except for a small fraction (less than 10%), all the inorganic phosphate is ionised, (Neuman and Neuman¹⁹³).

RELATION SERUM CALCIUM TO SERUM PHOSPHORUS.

Final conclusions as to the equilibrium between serum calcium and serum phosphorus have not been reached.

However, the important inference is that the body fluids are either saturated or at a constant degree of supersaturation or under-saturation in respect to some salt of calcium or phosphate so that, in the absence of any fluctuation in the pH, a rise in the calcium ions will lead to a fall in the phosphate ions and vice versa, (Albright and Reifenstein¹).

The adjustment of the total serum calcium to the serum phosphorus, when both are expressed in mgs. per 100ccs. is such that their product remains approximately constant, (Albright and Reifenstein¹).

PHYSIOLOGY OF BONE.

Bone is a plastic tissue which is constantly undergoing metaplasia; i.e., it is being formed in some places and destroyed in others, but both processes occur simultaneously. Under normal conditions, a status quo is maintained between bone formation and bone resorption, but under certain conditions, one or the other may predominate with subsequent distortion to the bone tissue.

The bone tissue of the body has a very great surface area, with the number of surfaces per unit of spongy bone being far greater than in compact bone (Albright and Reifenstein¹).

BONE FORMATION.

Bone formation, osteogenesis, presents an extremely complex picture which occurs always and everywhere, in the same way. The mother tissue is always loose connective tissue, (Weinmann and Sicher³⁰¹).

Weinmann and Sicher³⁰¹ propounded a three phase process to

explain the complete picture of bone formation, which essentially consists of:-

1. Osteoblasts produce a homogeneous, organic intercellular substance, primary osteoid.
2. This intercellular substance undergoes reorganisation, secondary osteoid.
3. Mineralisation of the reorganised tissue takes place.

OSTEOID.

A differentiating organic precursor of bone is formed to which the term "osteoid" specifically applies. Into this osteoid, deposition of inorganic salts takes place giving as a result, bone tissue, (Weinmann and Sicher³⁰¹).

Recent investigation by Loe¹⁵³ has shown the morphology and histochemistry of the osteoid at great length and with much detail. He disclosed three major zones of osteoid:-

1. Inner zone of young osteoid which is adjacent to the osteoblasts.
2. Outer zone, old osteoid, comprising the middle and peripheral parts of the osteoid which in turn borders on -
3. Transitional zone, a narrow area of tissue representing the end of the osteoid and the beginning of the bone tissue.

MECHANISM OF BONE FORMATION.

By analysis of these zones of osteoid, the process of bone

formation could be differentiated into three stages, each structural element being clearly defined, (Loe¹⁵³):-

STAGE I. - which includes the formation of precollagenous fibres and polysaccharides and ends with the development of mature collagen fibres and ground substance.

OSTEOBLASTS.- Osteoblasts seem to play a decisive role in bone tissue formation.

PRECOLLAGENOUS FIBRES.- The fibres formed by the osteoblasts appear as precollagenous fibres and are vastly more numerous than pre-existing fibres of the loose connective tissue, which are also incorporated in the osteoid formation.

CHONDROITIN SULPHATE.- The conversion of precollagen fibres into mature collagen fibres consists in the establishment of a firm connection between the precollagen fibres and chondroitin sulphate. The function of the chondroitin sulphate is thus considered to be that of a cementing substance.

ALKALINE PHOSPHATASE.- The reactions catalysed by this enzyme are not known, however, the association is with the development of collagen fibres.

NEUTRAL POLYSACCHARIDE - PROTEIN COMPLEX.- This complex is unaffected during the differentiation of the fibres, and constitutes the ground substance, rather than acting as a cementing substance between the fibres.

STAGE II. - shows the structural alteration of the collagen fibres with complete disappearance of the fibrous structures. The collagen does not respond to conventional stains, appears structureless and loses its characteristic bire-fringence.

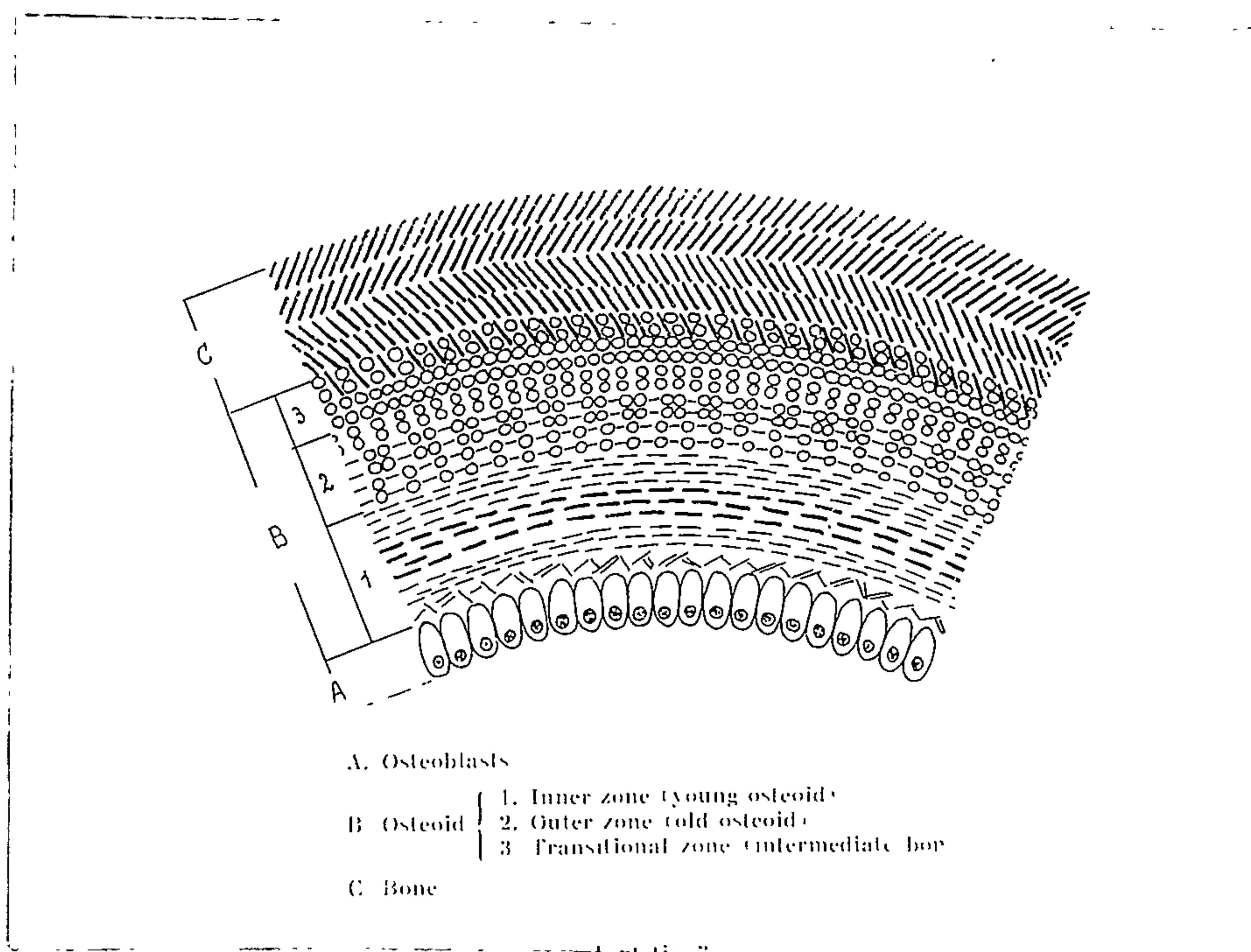


Fig. 3. Process of bone formation. After Loe.¹⁵³

This stage is thought to last for some considerable time.

STAGE III. - is comparatively brief, but comprises a complexity of processes directed towards the final transformation of the osteoid into calcifiable matrix and subsequent mineralisation.

RECONSTITUTION OF COLLAGEN FIBRES.

Initially the collagen fibres are reconstituted, probably as a result of loss of water leading to a higher concentration of non-fibrous collagen and aggregation of ground substance.

This reconstitution may be spontaneous or require a specific energy system mediated by enzyme systems of the osteoblastic processes.

"CALCIFIABILITY" OF THE MATRIX.

This is the stage when increased polymerisation of the ground substance, increased negative electric charge and reconstitution of the collagen fibres has occurred. Normally, however, the calcifiable matrix cannot be demonstrated because the matrix is mineralised as soon as calcifiability is brought about.

MINERALISATION.

The concept of calcification of osteoid tissue by precipitation from concentration of calcium and phosphorus ions has now been generally supplanted or modified. It was thought that a booster mechanism could be developed by which local concentration of calcium and phosphate would be raised above the critical ion product needed for precipitation, (Weinmann and Sicher³⁰¹).

Phosphatase is undoubtedly present in all calcifying areas and is thought to provide the means for liberation of free phosphate ions.

The mineralisation mechanism now generally accepted, is based

on the principle of epitaxy, or seeding, to elaborate a crystalline substance, (Neuman and Neuman¹⁹⁶).

The host crystal is without doubt organic, but whether the base collagen molecule, or some molecule structurally associated with collagen (mucopolysaccharide) is responsible for crystal induction, is open to question, (Neuman and Neuman¹⁹⁶).

The investigations of Loe¹⁵³ at the morphological level could not determine the actual crystallisation by either a booster mechanism or seeding mechanism.

BONE RESORPTION.

General Considerations.

The process whereby the elements of bone are destroyed or go into solution, is called resorption. It is, in effect, the putting into solution of a complicated structure, bone, in such a fashion that it disappears, its end products entering the blood stream, (McLean and Urist¹⁸⁴).

Since the work of Koelliker,¹³² in 1873, not very much more is known of the mechanism of bone resorption. It was he who named the osteoclast and made many observations of the process of bone resorption as follows:-

- 1) Resorption of bone always progresses inward from the surfaces of bone; it never arises within the deeper layers of the structure.
- 2) Bone mineral and bone matrix are removed simultaneously.
- 3) To allow the end products of the process to be removed via the blood stream, it is necessary for all the elements of the bone to be reduced to water soluble

substances to allow their transfer to the body fluids.

Of the components of bone, a small fraction is already in fluid form and this can be readily removed; the remainder is in solid form which is insoluble or soluble only with great difficulty in the aqueous fluids of the body.

RELATION OF RESORPTION PROCESS TO THE SEPARATE ELEMENTS OF BONE.

COLLAGEN.

At the temperature and hydrogen ion concentration of the body fluids, collagen can be dissolved by digesting or disintegrating its protein structure by various proteolytic enzymes such as pepsin (in vitro) and collagenase (in vivo). Participation by the enzyme, collagenase, has not been proved in this process, (McLean and Urist¹⁸⁴).

GROUND SUBSTANCE.

The close relation between the ground substance and interstitial fluid suggests that the former may be made soluble in water by a change in the state of polymerisation of the polysaccharide which it contains. Such changes are accompanied by an increase in the concentration of mucopolysaccharides in the blood, indicating that they are readily transferred to the fluid component, (McLean and Urist¹⁸⁴).

Hyaluronidase has been the enzyme suggested as mediating the depolymerisation of chondroitin sulphate, (McLean and Urist¹⁸²).

BONE MINERAL.

Chelating Agents.

The solution of bone mineral has proved a difficulty in the process of resorption, as the presence of an acid is required. However, this situation has been radically altered by the introduction of a group of compounds known as chelating agents, the prototype of which

is ethylenediamine tetra-acetic acid, Versene, (McLean and Urist¹⁸⁴).

Chelate structures exhibit greatly increased stability, lowered solubility in water and from the physiological point of view, the ability to ionise in solution much more readily than a substance such as calcium citrate.

The use of chelating agents in laboratory procedures for the decalcification of bones and teeth is common practice and may be carried out in neutral or even alkaline solutions.

This hypothesis in which chelating agents dissolve the bone mineral in vivo is neither proved nor disproved, however, as no known chelating agent has been shown to be present, (McLean and Urist¹⁸⁴, McLean¹⁷⁹).

SOLUBILITY OF BONE MINERAL UNDER PHYSIOLOGICAL CONDITIONS.

Neuman and Neuman¹⁹⁴ have made certain observations on the solubility of bone under physiological conditions from investigations made by themselves and other workers, which may be summarised as follows:-

- 1) Normal serum is supersaturated with respect to bone mineral and from this fact, inferences may be drawn concerning the mechanism of the regulation of bone-blood interrelations.
- 2) With respect to pH, Ca^{++} , P total, Na^+ the differences between serum and the extracellular fluid are minor.

If the serum is super-saturated, then so is the extracellular fluid. However, it is inconceivable that the mineral phase of bone should not be in equilibrium with its own fluid environment.

The interstitial fluid of bone cannot be supersaturated

with respect to bone mineral unless crystal formation is taking place.

- 3) It follows therefore, that the interstitial fluid of bone cannot be equivalent to the extracellular fluid in ionic composition.

Some diffusion barrier, ion gradient or pump must exist between these two fluid compartments.

It is suggested that the metabolic activity of the cells responsible for maintaining this ionic gradient, between the interstitial fluid of bone and the extracellular fluid compartment, is regulated by the action of vitamin D and the parathyroid hormone.

OSTEOCLASTS.

When bone is being resorbed, the area affected is strictly localised to that covered by osteoclasts, (Weinmann and Sicher³⁰⁰).

However, it is open to question as to whether the osteoclasts actually resorb the underlying bone or that their presence is merely incidental during the process of resorption.

Active participation by the osteoclasts is supported by McLean,¹⁷⁹ McLean and Urist,¹⁸⁴ but the factor or factors responsible for evoking and controlling this osteoclastic activity is unknown.

Hancox¹⁰³ has suggested a composite picture of the role of the osteoclast in action with which other authors are generally in agreement (McLean,¹⁷⁹ McLean and Urist,¹⁸⁴ Weinmann and Sicher³⁰⁰). Briefly summarising, the osteoclastic action could be as follows, (Hancox¹⁰³):-

- 1) In response to stimuli, physical or chemical, emanating from bone, osteoclasts are formed from the coalescence

- of their precursors and move to the site of action.
- 2) They flatten against the bone and secrete some substance which liquefies the ground substance.
 - 3) The bone salts are freed.
 - 4) The fibrillae are exposed and slowly digested away by the osteoclast which continues to pour out secretion between the fibrillae or fibril bundles so that the process of erosion is continuous.
 - 5) At the end of their life span, the osteoclast degenerates; it may move away, perhaps into the bloodstream, or perish locally near its site of action.

THE INFLUENCE OF THE ENDOCRINE GLANDS ON BONE AND BONES.

General Considerations.

"The over-all function of the endocrine glands is that of catalysis, that is, acceleration or retardation of basic enzyme systems within the cells themselves," (Resch²²⁵).

The specific products, hormones, elaborated by the endocrine glands are secreted into the blood stream and thus are carried from the place of origin to all parts of the body, (Weinmann and Sicher³⁰⁶).

The interaction of the endocrine glands is extremely complex, since interference with the function of one influences one or possibly more of the other components of the endocrine system. This interaction of the ductless glands is known as the endocrine balance, (Weinmann and Sicher³⁰⁶).

It is the quantitative, not the qualitative, changes in cer-

tain hormones which disturbs the endocrine balance. Deficiency in the production of a hormone may be caused by atrophy of the glandular cells, surgical removal of part or all of the gland, or congenital absence of the gland.

An overproduction of a hormone is caused by hypertrophy or proliferation of the functional elements of the gland, (Weinmann and Sicher³⁰⁶).

The endocrine glands which are known to influence bone and bones are, (Weinmann and Sicher³⁰⁶):-

1. Pituitary gland
2. Thyroid gland
3. Sex glands or gonads.
4. Parathyroid glands.

PITUITARY GLAND.

The pituitary gland is often regarded as the master gland of the body because of its influence on other endocrine glands, (Weinmann and Sicher³⁰⁶).

It is generally agreed that six hormones are elaborated by the pituitary gland, two of which act directly on target organs, the growth-promoting and the lactogenic hormones.

The other hormones, the two gonadotrophic hormones, the thyrotrophic and the adrenocorticotrophic hormone, act indirectly by stimulating the respective endocrine glands, (Weinmann and Sicher³⁰⁶). However, Silberberg and Silberberg²⁵⁶ are of the opinion that there is sufficient direct and circumstantial evidence to indicate strongly that the steroid hormones, i.e., hormones of the gonads and adrenal cortex, may act directly on the skeleton without mediation of the

pituitary hormones.

The growth hormone acts directly and the thyrotrophic hormone indirectly, to simulate skeletal growth. The final effect of the gonadtrophic and adrenocorticotrophic hormones is antagonistic, inhibiting growth, (Weinmann and Sicher³⁰⁶ and Silberberg and Silberberg²⁵⁶).

In both over-secretion and under-secretion of the pituitary growth hormone, a proportionate or disproportionate growth results. The degree of growth disturbance depends on the time of onset of the endocrine irregularity.

Hyperpituitarism may be seen in the condition of giantism in the developing child or adolescent and acromegaly, with considerable disproportionate growth in the adult.

Hypopituitarism is similarly characterised, according to the time factor, with pituitary dwarfism or acromicria resulting.

THYROID GLAND.

The thyroid gland primarily regulates the rate of cellular oxygen metabolism and metamorphosis and secondarily affects growth and development, (Resch²²⁵).

Activation of the thyroid gland by the thyrotrophic hormone of the pituitary gland is essential to skeletal growth. However, hypopituitarism and hypothyroidism differ widely from each other - mental ability is unimpaired in the pituitary dwarf and greatly depressed in the thyroid dwarf, (Weinmann and Sicher³⁰⁶).

Interdependence between the thyroid and pituitary glands may be seen when excess thyroid hormone inhibits the production of thyrotrophic hormone and thus limits indirectly the activity of the thyroid

gland, (Weinmann and Sicher³⁰⁶).

MALE AND FEMALE SEX GLANDS.

Development and maturation of the sex glands is dependant upon the production of the gonadtrophic hormones from the pituitary gland, (Weinmann and Sicher³⁰⁶).

With maturation, the male sex hormones and the primary female sex hormone act finally as inhibitors upon the growth-promoting hormone of the pituitary gland. Therefore, sexual maturation of the species initiates the termination of somatic growth, (Weinmann and Sicher³⁰⁶).

FEMALE SEX HORMONES, OESTROGEN AND PROGESTERONE.

OESTROGEN.

The primary sex hormone, oestrogen, has been shown to have a definite influence on skeletal growth, however, the mode of action has not been satisfactorily shown. Silberberg and Silberberg²⁵⁶ have summarised current hypotheses as to the inhibiting oestrogenic effect on bone as follows:-

- 1) Oestrogen induces hyalinisation of the ground substance.
- 2) Oestrogen causes primary osteoclasia and osteolysis associated with or followed by excessive medullary bone formation.
- 3) Oestrogen injures the reticulum cells of the bone marrow.

The majority of investigations on which the above hypotheses are based, has been carried out on birds. It has been assumed that the response of avian and mammalian mesenchyme may be similar, but modified in birds by the hypercalcaemic response to the developing egg, (Silberberg and Silberberg²⁵⁶).

The anabolic effect of oestrogen on mesenchymal tissues has not received supportive evidence. Whether oestrogen stimulates primary osteoblastic growth provides much thought, particularly in relation to the osteoporosis observed in the post-menopausal female where the oestrogen production is greatly diminished, (Silberberg and Silberberg²⁵⁶).

PROGESTERONE.

The effects of progesterone on calcium metabolism and bone have not, as yet, proven to be of any significance, (Silberberg and Silberberg²⁵⁶).

However, progesterone, which is necessary for pubic relaxation in normal gestation, acts in many ways antagonistically to oestrogen, notably during pregnancy, (Weinmann and Sicher³⁰⁶).

MALE SEX HORMONES. ANDROGENS.

The skeletal effects of testicular deficiency resemble those caused by ovarian deficiency. The male sex hormones, androgens, androsterone, testosterone can be compared in their effect with the oestrogens, (Weinmann and Sicher³⁰⁶).

However, some overlapping of the effects of the androgens and the adrenocortical steroids occurs in the aged person which complicate the changes observed in bone tissue, (Silberberg and Silberberg²⁵⁶).

PARATHYROID GLANDS.

The parathyroid glands supply a secretion, the parathyroid hormone which is intimately concerned with the calcium ion concentration in the blood.

There is no evidence of its effect upon the deposition of the bone mineral, but the regulation of the serum calcium is accomplished solely by an influence of the parathyroid hormone upon the solution of bone mineral, (McLean and Urist¹⁸⁵).

Albright and Reifenstein¹ describe four cardinal metabolic changes which occur when the parathyroid hormone is withheld, either by removal of the parathyroid glands or cessation of parathyroid extract therapy in a hypoparathyroid patient. These changes are:-

- 1) An immediate decrease in the phosphorus excretion in the urine.
- 2) Rise in the serum phosphorus level.
- 3) Almost simultaneously a fall in the serum calcium.
- 4) With fall in the serum calcium, there is a diminished calcium urinary excretion.

The same four metabolic functions are altered in the opposite direction but in the same sequence if parathyroid extract is administered to a normal or hypoparathyroid individual namely:-

- 1) Hyperphosphaturia
- 2) Hypophosphataemia
- 3) Hyperealcaemia
- 4) Hypercalcuria

The theory of a solubility product constant, related to serum phosphorus and serum calcium, seems probable from these observations of the direct effect of parathyroid hormone, (Albright and Reifenstein¹).

Attempts have also been made to relate the mode of action of the parathyroid hormone to the observed metabolic changes. The proposed suppositions have been summarized by Weinmann and Sicher³⁰⁶ as follows:-

- 1) The parathyroid hormone primarily increases the power of the blood plasma.
- 2) The parathyroid hormone primarily stimulates the differentiation of osteoclasts and thus initiates the resorption of bone.
- 3) The parathyroid hormone primarily acts upon the kidney. This suggestion is supported by Albright and Reifens¹stein¹ who believe that the kidneys, in their role of controllers of homeostasis, keep the calcium and phosphate levels in the body fluids at such heights that calcium phosphate will be constantly resorbed at bone resorbing surfaces.

Weinmann and Sicher³⁰⁶ feel that singly these suppositions do not explain the action of the parathyroid glands. The working hypothesis which they present is that the function of the parathyroid hormone is to maintain the optimum calcium blood level which it does by:-

- 1) Causing osteoclastic resorption of bone. Calcium can only be drawn from the skeleton by resorption of bone, which occurs by differentiation of the osteoclasts by the parathyroid hormone.
- 2) Increasing excretion of phosphorus. During resorption, phosphorus is also mobilised and the rise of the serum phosphorus is counteracted by the second function of the parathyroids, the direct influence on the kidneys.
- 3) Inhibiting calcification of newly formed bone. Parathyroid hormone acts antagonistically to Vitamin D,

although they both have a common function to maintain calcium blood level. Under normal circumstances, the antagonism of Vitamin D and parathyroid hormone is resolved into an equilibrium.

THE INFLUENCE OF VITAMINS ON BONE AND BONES.

Vitamins are ingested in small quantities in the average diet and distributed by the blood stream to all the organs of the body. Their mode of action is essentially similar to that of hormones, that is acting in specific ways upon the different tissues (Weinmann and Sicher³⁰⁷).

VITAMIN A.

The fat soluble vitamin A is contained in eggs, milk and liver while provitamin A, carotene, is found in yellow and green vegetables. Transformation of the provitamin to vitamin A probably occurs in the intestinal mucosa, (Weinmann and Sicher³⁰⁷).

HYPOVITAMINOSIS A.

Apart from night blindness, which is characteristic of vitamin A deficiency, the following tissue changes may be observed:-

- 1) The various epithelia of the body undergo metaplastic change, the more differentiated epithelia regress to the simple stratified type and those which are normally stratified become more cornified, (Barnicot and Datta¹⁵).
- 2) Suppositions on the bony changes in man have been based on experimental work using dogs and rats. The results suggest that vitamin A acts as a specific chemical con-

troller of the activities of osteoblasts and osteoclasts. The exact way in which this control is exercised is, however, unknown, (Barnicot and Datta¹⁵).

HYPERVITAMINOSIS A.

With hypervitaminosis A, there seems to be increased osteoclastic and reduced osteoblastic activity, with some deficiency in calcification of the osteoid tissue.

Investigations on rats and mice revealed extensive bone resorption, in the absence of typical reparative processes, in the supporting bone of the alveolar process in regions most subject to stress, (Weinmann and Sicher,³⁰⁷ Barnicot and Datta¹⁵).

VITAMIN C.

Vitamin C, ascorbic acid, is contained in highest concentration in citrus fruit, green peppers and leafy vegetables, (Weinmann and Sicher³⁰⁷).

Deficiency of the vitamin results in the condition of scurvy, which shows the characteristic clinical symptoms of extensive muscle and joint haemorrhages of the extremities; swelling and bleeding of the gingiva and loosening of the teeth; failure of wounds to heal.

All these symptoms may be related to the specific action of vitamin C on connective tissue cells. It is generally agreed that this vitamin is necessary for the normal formation and maintenance of collagen fibres, although there is no certainty as to the mechanism by which this process is effected, (Weinmann and Sicher³⁰⁷).

In vitamin C deficiency, there is a general lowering of normal cellular metabolic activity and presumably differentiation of the

cells responsible for the elaboration of the intercellular substances is impaired, (Bourne²⁷).

With respect to bone tissue, osteoclasts and their resorptive activity seem to be unaffected by vitamin C deficiency, however, osteoblastic activity is greatly restricted, (Weinmann and Sicher³⁰⁷). Unfortunately, these observations are insufficient to explain scorbutic osteoporosis as a result of restricted apposition and normal resorption of bone.

Bourne²⁷ suggests that the lowered cellular metabolic activity in vitamin C deficiency does not fully explain the reduction in organic bone matrix formation. Both chondroitin sulphate and phosphatase activity appear to be depressed, the former possibly due to a disturbance in its synthesis and the latter by a decrease in the amount of phosphate impregnated matrix.

Certainly it has been established that vitamin C deficiency is associated with profound changes in connective tissues, including bone, (Bourne²⁷).

VITAMIN D.

The average diet is poor in vitamin D but contains sufficient amounts of the provitamin, ergosterol, which changes into vitamin D on irradiation with ultraviolet rays. The change of ergosterol to vitamin D occurs in the skin, where it is stored, (Weinmann and Sicher³⁰⁷).

The main sources of vitamin D are egg yolk and dairy products while ergosterol is found in fats.

Vitamin D deficiency is caused mainly by failure of the body to change ergosterol to vitamin D because of insufficient exposure

to sunlight.

MODE OF ACTION OF VITAMIN D.

The main function of vitamin D is regulation of the calcium-phosphorus metabolism by maintaining the absolute level and the physiological ratio of these two minerals, (Weinmann and Sicher³⁰⁷).

It is assumed that vitamin D facilitates the absorption of calcium through the mucous membrane of the intestinal tract, (McLean and Urist,¹⁸⁶ Jenkins¹²¹ and Keating¹²⁸). There is little or no evidence that vitamin D acts in a direct way upon the function of the alimentary canal as such, although a deficiency in vitamin D causes an increased loss of phosphorus, or calcium, or both in the faeces, (Harris¹⁰⁵).

HYPOVITAMINOSIS D.

The symptoms of vitamin D deficiency in childhood are represented by the condition of rickets. After termination of growth, the formation of new bone does not contribute significantly to the growth of the skeleton, but is a factor in the normal bone reconstruction process.

In the adult, gradual replacement of well calcified bone by uncalcified osteoid tissue occurs, primarily by depression of calcium absorption from the intestinal tract and secondarily by a depletion of phosphorus. This loss of phosphorus is increased by the hyperfunction and hyperplasia of the parathyroids which are released from the inhibiting influence of vitamin D, (Weinmann and Sicher³⁰⁷).

The resulting osteoporosis may be severe, and continue for a long time. Therefore, after a period of vitamin D deficiency, parts

of bones or the entire bones will consist of osteoid tissue, also showing the signs of rarefaction, (Weinmann and Sicher³⁰⁷).

HYPERVITAMINOSIS D.

In very large doses, 50,000 International units daily, vitamin D brings about mobilisation of minerals from the skeleton which is similar in effect to a hyperparathyroidism, (McLean and Urist¹⁸⁶). This is only a superficial similarity however, as the two processes are fundamentally different.

Whereas parathyroid hormone raises the blood calcium level by withdrawing the mineral from the bones and causing a loss to the body as a whole, vitamin D decreases the faecal loss of calcium and thereby increases its retention in the organism, (Harris¹⁰⁵).

RELATION OF VITAMIN D AND THE PARATHYROID HORMONE.

The function of the parathyroid hormone and vitamin D is mutual, that is maintenance of the blood calcium level. However, the mechanisms by which this is done are completely different. The action of vitamin D can be described as increasing the utilisation of external, dietary resources of calcium, while the parathyroid hormone mobilises calcium from internal deposits, from bone, (Weinmann and Sicher³⁰⁷).

As has been previously mentioned, an equilibrium is effected between these apparently antagonistic mechanisms of action of the parathyroid hormone and vitamin D, (Weinmann and Sicher³⁰⁷).

METABOLIC DISEASE OF BONE.

INTRODUCTION.

Considerations have been made of the various aspects, anatomical, histological etc., of bone both as a tissue and, to some extent, as

an organ. The multiplicity of influences, which regulate the normal functioning of bone and bones in the clinically "healthy" individual, suggests that a sub-clinical examination would present a rather different picture.

The indications of metabolic bone disease may, or may not, be clinically obvious. However, the association with certain conditions can be anticipated with such certainty, that a full investigation must be made.

The influence of hormones, vitamins and minerals on bone have been examined and it is not proposed to reconsider each one here; rather is it the aim to present a general summary of the conditions associated with the metabolic disease state of bone.

CLASSIFICATION.

Metabolic disease of bone may be classified according to the quantity and quality of bone tissue. The multiplicity of factors which influence the normal physiology of bone, endocrine, nutritional, functional etc., make further classification extremely complex due to the overlapping between these influences.

Albright and Reifenstein² have suggested that the two main divisions of metabolic bone disease should be:-

1. "Too-Little-Calcified Bone."
2. "Too-Much-Calcified Bone."

From the clinical application in prosthetic practice, it is the former group which has greater significance, in that either the quantity or the quality of bone tissue is deficient - or even both.

As a result, the following sub-classification has been used, (Albright and Reifenstein²):-

A) Bone formation too little.

a) Defect in matrix formation: Osteoporosis.

b) Defect in calcification of matrix: Osteomalacia.

B) Bone resorption too much.

a) Osteitis Fibrosa Generalisata.

OSTEOPOROSIS.

DEFINITION.

In osteoporosis the decrease in bone tissue is due to the fact that the osteoblasts lay down too little bone matrix; that matrix which is laid down is normally calcified, (Albright and Reifenstein²).

When due to a systemic cause, osteoporosis shows a marked predilection for the vertebrae, pelvis and skull and seldom involves the extremities, (Albright and Reifenstein³).

DIAGNOSIS.

As osteoporosis is a disease of tissue metabolism, normal serum calcium and phosphorus levels are maintained, (Albright and Reifenstein³).

Radiographically, approximately 30% of calcium needs to be lost from the skeleton before being obvious, and it is estimated that this degree of calcium loss takes from four to nine years, (Rhydderch²²⁹).

The radiograph of an osteoporotic condition shows that there is a reduction in the number and size of the trabeculae, as well as a general thinning of the cortex, (Benjamin¹⁸). However, the lamina dura around the teeth remains characteristically intact, (Albright and Reifenstein³).

CONDITIONS ASSOCIATED WITH OSTEOPOROSIS.

DISUSE ATROPHY.

It is generally agreed that mechanical forces applied to bone are necessary to stimulate the apposition of new bone, (Weinmann and Sicher³⁰⁵, Albright and Reifenstein³).

These forces are, therefore, necessary for the replacement of bone that is lost in the normal course of events. Disuse atrophy may then be regarded, not so much a direct loss of non-functional bone, but a lack of replacement of lost bone, (Weinmann and Sicher³⁰⁵).

Bone tissue as such, is resistant to the forces of both pressure and tension. Weinmann and Sicher³⁰⁵ suggest that the resistance to tension is the property of the uncalcified fibrils, the resistance to pressure the property of the calcified cementing substance of the tissue.

The behaviour of bone under pressure depends on the different degree, direction and duration - whether continuous or intermittent - of the forces being applied. Provided the pressure does not diminish or destroy the blood supply or interfere with the venous drainage of the bone tissue, normal osteoblastic activity is not impaired, (Weinmann and Sicher³⁰⁵).

With disuse atrophy, the stimulus of forces of both pressure and tension are reduced, leading to decreased osteoblastic activity, (Albright and Reifenstein³).

The association of disuse atrophy with aging, post-menopausal and nutritional states is common, (Albright and Reifenstein³).

NUTRITIONAL DEFICIENCY.

The part played by the diet in osteoporosis has not been success-

fully established except in vitamin C deficiency - this has been previously discussed.

The most likely conclusion is that a diet inadequate in protein may lead to a negative nitrogen balance which may make it impossible for the osteoblasts to lay down the necessary organic matrix. Albright and Reifenstein³ consider that many osteopathies attributed to a calcium and phosphorus deficiency in the diet, have been due to protein starvation.

POST-MENOPAUSAL STATE.

The most common form of osteoporosis is thought to be associated with the post-menopausal state in which there is a hormonal disturbance with reduced production of the primary female sex hormone, oestrogen, (Albright and Reifenstein³). The mode of action of oestrogen has already been considered.

A moderate degree of osteoporosis of the spine after the menopause may be considered almost physiological; its degree increases as the time the post-menopausal state has existed increases, (Albright and Reifenstein³).

Treatment of patients in which this condition exists, may consist of carefully controlled administration of either androgen or oestrogen, possibly both. Silberberg and Silberberg²⁵⁶ suggest that androgen therapy is more satisfactory as the material can be controlled more easily.

AGING.

The majority of changes in old age are essentially due to atrophy of the tissues; this is reflected in the skeleton as osteoporosis. The hypofunction of the steroid-producing glands, sex glands and

adrenal cortex, has been suggested as being a dominant factor in producing senile changes of the tissues, however, this is as yet unsubstantiated, (Albright and Reifenstein³).

In many cases, the osteoporosis of disuse, malnutrition, post-menopause and senility are inseparably superimposed.

OSTEOMALACIA.

DEFINITION.

In osteomalacia, there is too little calcified bone due to the fact that there is a disorder of calcium or phosphorus metabolism so that mineral is not deposited in the newly formed osteoid. The bony tissue is therefore less resistant to stresses and strains and this results in an over production of osteoid by the osteoblasts, (Albright and Reifenstein²).

DIAGNOSIS.

The expected findings in osteomalacia are normal or low serum calcium, a low or normal serum phosphorus (most commonly a normal serum calcium with a low serum phosphorus), and a high serum alkaline phosphatase level, (Albright and Reifenstein²).

CONDITIONS ASSOCIATED WITH OSTEOMALACIA.

Any condition where there is primarily a depression of calcium absorption from the intestinal contents and secondarily a depletion of phosphorus will produce osteomalacia.

Nutritional deficiencies of calcium and vitamin D, intestinal malfunction, kidney insufficiency and secondary hyperfunction and hyperplasia of the parathyroids may all play some part in the production of osteomalacia, (Weinmann and Sicher,³⁰⁷ Albright and Reifenstein⁴).

OSTEITIS FIBROSA GENERALISATA.

In osteitis fibrosa generalisata there is a decrease in bone tissue as a whole because of increased bone resorption. This leads to decreased bone strength, and this in turn to an increased activity on the part of the osteoblasts and hence to a high serum alkaline phosphatase level,¹(Albright and Reifenstein²).

The commonest cause of osteitis fibrosa generalisata is hyperparathyroidism, which, if present, is associated with high serum calcium and low serum phosphorus levels, (Albright and Reifenstein²).

CHAPTER III.

ANATOMICAL CONSIDERATIONS OF THE ALVEOLAR PROCESS.

ALVEOLAR PROCESS - DEFINITION.

In the upper arch, the bony maxillae provide the supporting framework for the natural dentition. Projecting downwards from the maxillae is a thick curved ridge which carries the teeth and bounds the bony palate in front and at the sides, (Cunningham⁵⁴).

This projection is known as the alveolar process of the maxilla. It is so named from the word "alveolus" which is defined as a "bony socket of a tooth," (Blakiston²⁴).

When teeth are removed from a dried skull, then a row of sockets or "alveoli" remain, hence giving the name of "alveolar process" to the supporting bone.

With the removal of teeth during life, the walls of the corresponding sockets are soon resorbed, and the size of the alveolar process in these places is considerably reduced in size and form, (Cunningham⁵⁴).

Therefore, the maxillary alveolar process may be defined as that part of the upper jaw bone which gives support to the teeth or their artificial substitute, (MacWilliam¹⁷⁶).

The posterior part of the maxillary alveolar process is termed the tuberosity of the maxilla, of which there are two, (Cunningham⁵⁴).

DEVELOPMENT AND GROWTH.

The development and growth of the alveolar process is by

intensive apposition of bone at the free borders of the alveolar process; particularly during the eruption of the permanent dentition, (Weinmann and Sicher³⁰³).

This increase in height to the subnasal part of the maxilla, together with the sutural growth at the frontomaxillary, zygomatic-maxillary and pterygopalatine sutures, is responsible for the downward and forward shift respectively, of the upper jaw, (Weinmann and Sicher³⁰³).

As was realised by Brodie²⁸ "the growth of the alveolar process probably contributes more to the height of the face than does growth of any other part."

Coincident with this vertical and antero-posterior growth of the maxillae, the posterior end of the alveolar process is brought in line with the lower end of the pterygoid process to provide widening in transverse dimension. Both median palatine sutural growth and downward divergent growth of the pterygoid processes of the sphenoid bones produce this widening of the alveolar process, (Weinmann and Sicher³⁰³).

The development and eruption of the teeth is necessary for the development and growth of the alveolar process, (Orban²⁰⁶). Not only does the alveolar process fail to develop if a tooth or teeth are absent but it disappears if teeth are lost, according to Weinmann and Sicher.³⁰⁴ This latter statement must be qualified to suggest "partial disappearance," which is in line with the clinical picture as presented to the prosthodontist.

O'Meyer,²⁰¹ in a cephalometric group study of 30 individuals

aged 4-20 years, showed a reduction in height of the alveolar process during the period of loss of the deciduous dentition and replacement by the permanent teeth. The destruction and rebuilding of the alveolar process to its previous height requires approximately four to five years and occurs only in the areas of the deciduous dentition.

STRUCTURE.

No distinct boundary exists between the body of the maxillae and its alveolar process. Fusion between basal bone and bone of the alveolar process is indeterminate, (Orban²⁰⁶).

However, the structure of the alveolar process can be divided into two parts, (Orban²⁰⁶).

- 1) The thin lamella of bone which surrounds the root of the tooth and gives attachment to principal fibres of the periodontal membrane. This is called the alveolar bone, (Dorland⁷⁰) alveolar bone proper (Orban²⁰⁶) cribriform plate, or more commonly, lamina dura. This thin layer consists partly of lamellated and partly of bundle bone.

The more dense appearance radiographically is due to the bundle bone which contains a greater amount of cementing substance per unit volume and consequently bone salts per unit volume, (Weinmann and Sicher³⁰²).

The number of fibrils is also much less with no distinguishable arrangement of the bone in lamellae, (Weinmann and Sicher³⁰² Orban²⁰⁶).

- 2) The bone which surrounds the lamina dura and gives support to the tooth sockets and which is called supporting bone, (Orban²⁰⁶).

This, in turn, consists of two parts: the compact bone (cortical plate) forming the vestibular and oral plates of the alveolar processes, and the spongy bone between these plates and the alveolar bone proper, lamina dura, (Orban²⁰⁶).

The cortical plates, continuous with the compact layers of the maxillary basal bone, vary in thickness. Anteriorly, the cortical plate is fused for some distance with the lamina dura of the tooth socket on the labial.

Many small openings perforate the outer (buccal and labial) cortical plate, through which blood and lymph vessels pass, (Orban²⁰⁶).

Histologically the cortical plates consist of longitudinal lamellae and haversian systems, (Orban²⁰⁶).

The spongy bone varies in density and thickness according to the functional demands and location respectively. Anteriorly there is little or no spongy bone.

The marrow spaces may contain haemopoietic tissue but usually contain fatty marrow, (Orban²⁰⁶).

The interdental and interradicular septa contain perforating canals which house the interdental and interradicular arteries, veins, lymph vessels and nerves. The crest of these septa are dependant upon the

position of the adjacent teeth.

In a normal healthy mouth the teeth are tipped mesially and therefore the alveolar crest slopes distally, (Orban²⁰⁶).

ARCHITECTURAL ARRANGEMENT.

GENERAL.

The architectural arrangement of the alveolar process is regulated by the response of the elements of the bone tissue to the functional demands placed on it. The internal and external architecture are constantly changing throughout life and the remodelling which occurs, is evidence of the ability of the process to accommodate itself to functional demands as imposed during the growth, eruption, wear and loss of the teeth, (Orban²⁰⁷).

MacWilliam¹⁷⁶ showed an awareness of this when he stated:-

"the influence of the accessory factors concerned in mastication, and all the remaining factors, pathologic and otherwise, which may affect individual bones or the osseous system in general are as indelibly imprinted on the structure of the alveolar process as are environmental influences on the head of the femur."

The cancellous or spongy bone is the part of the alveolar process which has its internal structure - trabecular pattern - so arranged in the form of trajectories, as to best meet the forces applied to it in function. This pattern changes continuously during growth of the alveolar process and in response to alterations in stress distributions, (Orban²⁰⁷).

TRABECULAR ARRANGEMENT.

There have been numerous investigations by authors on the

trabecular arrangement in the jaws of animals (Seipel²⁴⁹) and man, (Neufeld,¹⁹² Seipel²⁴⁹).

Seipel²⁴⁹ was responsible for some excellent work in which he used a refined crevice-line preparation as an indicator of structural arrangement and by means of micro-dissection and histologic sections elucidated the interior architecture in the jaws of man and chimpanzee. This architecture is referred to the organic matrix and is formed by lamella-systems of different order, or by a fibrillar arrangement in fibrous strands, in bundles or net-work.

The results of Seipel's²⁴⁹ work showed:-

- 1) The organic pattern of the jaw bones has a fairly regular and constant occurrence, comparable to the interior organisation of other organs (like the liver, heart, muscle etc).
- 2) The maxillary alveolar process shows:-
 - a) a system of border parallel and circular fibres around the necks of the teeth, inserting into the more porous bone of the interdental septa or continuing interdentally to form a more or less complete circular architecture around the teeth. Posteriorly it is intermixed with the longitudinal alveolar architecture which spreads out over the tuber maxillae from the premolar region backwards on the buccal.
 - b) a system of root parallel trajectories, the ascending alveolar system, above the circular and longitudinal alveolar architecture on the buccal. The bone covering the roots is usually thinner with a tendency towards arcade formation at the apices of

the teeth. In the mid-line there are few cross-connecting lines.

The molar region is marked by an increasing amount of longitudinal trajectories along the alveolar margin with a net-like texture of the tuber area. The bone here shows a diffuse architecture and a spongy appearance. Microscopically it appears as a fairly dense network of collagenous fibrils and lamellar systems.

- 3) A palatine arrangement which is rather diffuse in its trajectorial arrangement, showing only weak structural organisation.

CONCLUSION: The alveolar process of the maxillary bone provides the origin for the architectural and trajectorial systems of the upper jaw. From there on, the bone texture forms more or less clear tracts towards the insertion areas of the muscles of mastication and the neurocranium.

ELECTRONMICROSCOPY STUDIES.

Frank, Lindemann and Vedrine⁸³ examined normal human alveolar bone in thin sections by electronmicroscopy. The results of their examination showed a characteristic longitudinal arrangement of the collagenous fibres in the form of arched or featherlike bundles. These fibre arrangements are either irregular or almost parallel.

The inorganic component of alveolar bone showed a diffraction pattern similar to hydroxyapatite with the long axes of the crystals parallel to the collagenous fibres.

RELATION OF RADIOGRAPHIC EVIDENCE WITH HISTOLOGICAL INVESTIGATION.

The problem of correlating the clinical radiograph with the histologic structures in the alveolar process has been considered, (Rogers and Applebaum,²³² Applebaum,⁸ Neufeld¹⁹²).

Rogers and Applebaum²³² and Neufeld¹⁹² agree that normal clinical X-rays reveal the architecture of bone of the mandible as effectively as ground and decalcified sections.

Applebaum⁸ showed variations in radiopacity of histologic structures in alveolar bone, not quite visible in a clinical radiogram, by using grenz ray studies of ground sections. The aim was to aid the clinician to correlate clinical X-ray findings with basic histologic studies.

CONCLUSION:

As stated by MacWilliam¹⁷⁶ and supported by Orban²⁰⁷ :-

"In development, in response to stimuli, in regeneration, in any comparison with the remaining osseous tissue, there is no bone which is more characteristically TRUE BONE than the alveolar process."

When this fact is appreciated, then it is possible to relate the changes observed in the alveolar processes following tooth extraction and surgical procedures, to the biological and physiological aspects of bone as a tissue.

MUCOUS MEMBRANE OF THE ALVEOLAR PROCESS.

GENERAL.

The oral cavity throughout is lined by a mucous membrane, whose morphologic structure is variable in different areas according to the specific functions and mechanical influences to which it is subjected.

Orban^{208, 204} has divided the mucous membrane of the oral cavity into three zones:

- 1) Specialised mucosa covering the dorsal surface of the tongue.
- 2) Masticatory mucosa covering the gingiva and hard palate.
- 3) Lining mucosa covering the remaining area as a protective lining.

Based on this classification, the mucosa of the alveolar process consists of:-

- 1) Masticatory mucosa.
- 2) Lining mucosa.

1) MASTICATORY MUCOSA.

Of principal concern to this study is the gingiva of the masticatory mucosa, which is separated from the lining mucosa by a scalloped line, the mucogingival junction. It is well developed on the buccal surface of the maxilla but poorly defined on the palatal surface.

The gingiva is subjected to forces of friction and pressure during the process of mastication and is well adapted to meet these stresses. Normally the epithelium is hornified on its surface and contains a granular layer; however, transition from parakeratotic to nonhornified surface epithelium may be considered normal.

The epithelium covers the margin of the gingiva and continues over and into the gingival sulcus to terminate on the surface of the tooth as the epithelial attachment.

The lamina propria of the gingiva consists of dense connective tissue which is not highly vascular. The gingival fibres of the periodontal membrane enter into the lamina propria attaching the gingiva firmly to the teeth. Similarly, the gingiva is firmly attached to the periosteum of the alveolar bone by means of dense connective tissue, consisting of coarse collagenous bundles extending from the lamina propria to the bone.

The submucous layer cannot be clearly defined in the gingiva due to these attachments of the lamina propria, (Orban^{208, 204}).

2) LINING MUCOSA.

The alveolar mucosa of the maxillary alveolar process extends superiorly from the mucogingival junction. It is red in colour showing numerous small vessels close to the surface.

The dense connective tissue of the lamina propria is clearly differentiated from the loosely textured submucosa, which binds the mucosa movably to the periosteum of the alveolar bone. Numerous elastic fibres and sometimes mucous glands are present in the lamina propria.

The surface of the alveolar mucosa is smooth and the epithelium is not hornified, (Orban^{208, 204}).

ALVEOLAR PERIOSTEUM.

Periosteum is a specialised connective tissue covering the external surfaces of bone. The attachment of the periosteum to the alveolar process is tight, due to the continuation of dense collagenous bundles from the periosteum into the bone as Sharpey's fibres.

At such places, large blood vessels and nerves enter the bone, (Maximow and Bloom¹⁶⁶).

The periosteum consists of two layers which are not sharply defined:—

- 1) External layer which is a network of dense connective tissue containing blood vessels.
- 2) Deep or cambium layer where the collagenous bundles are more loosely arranged.

Blood vessels pass through the external layer, enter the deep layer and then to the haversian canals through the canals of Volkmann.

Under normal conditions in the healthy adult, the periosteum has no osteogenic function, however, with fracture, the bone forming potentialities are activated and osteoblasts reappear in the deepest layer of the periosteum, (Maximow and Bloom¹⁶⁶).

PERIODONTAL MEMBRANE.

The periodontal membrane is the connective tissue which surrounds the root of a tooth to attach it to the bony alveolus, (Maximow and Bloom,¹⁶⁷ Orban,²⁰⁵ Kronfeld¹³⁵).

The principal fibres of the periodontal membrane are white collagenous connective tissue fibres, without any elastic fibres present.

The apparent elasticity of the periodontal membrane is due to the arrangement of the fibre bundles which follow a wavy course from bone to cementum, and so allow slight movement of the tooth under stress, (Orban²⁰⁵ Kronfeld¹³⁵).

The principal fibres of the periodontal membrane are anchored

in the bundle bone of the lamina dura by a continuation into the bone as Sharpey's fibres (Orban²⁰⁶). Orban²⁰³ showed that when teeth move under normal physiological forces, the side from which the movement occurs is rich in Sharpey's fibres with the deposition of new bundle bone ensuing.

Frank, Lindemann and Vedrine⁸³ under electronmicroscopy describe Sharpey's fibres and also soft white flexible fibres entering the lamina dura and which, they believe, contribute to the formation of the collagenous matrix of the alveolar bone. These fibres are impregnated with bone salts.

A zone of less calcified alveolar bone has been described by these workers (Frank et al.⁸³) which is adjacent to the periodontal membrane and appears to be in the middle stage of differentiation. They suggest this zone may be called a "preosseous stage."

EDENTULOUS ALVEOLAR PROCESS.

The classical studies of Pendleton^{214, 215} and Pendleton and Glupker²¹⁶ have provided detailed histological data of the edentulous maxilla and mandible. From this data, the prosthodontist has been able to construct dentures which follow sound biological principles.

In the subject of this review, immediate dentures provide the transition from the completely or partially dentulate state, to the edentulous. Therefore, a consideration of the edentulous alveolar process and covering mucosa is pertinent.

CLASSIFICATION OF AREAS OF SUPPORT.

Pendleton²¹⁴ divided the area covered by a maxillary denture into: -

- a) Primary stress-bearing area.
- b) Relief area.
- c) Secondary stress-bearing area.
- d) Valve producing area.

There is a marked consistency in the type, location and distribution of the tissues found in each area although the structures vary greatly in character in the different regions of the upper jaw, (Pendleton²¹⁵).

Based on the above classification, the primary stress bearing area includes the residual ridges to the point of insertion of the muscles on the buccal and labial, and to the compressible structures on the palatal surface. Therefore, the primary stress bearing area and edentulous alveolar process are one and the same.

STRUCTURE.

The bony ridge of the edentulous alveolar process varies greatly, the principal variation being evidenced in the extent of its development and the degree of resorption which has taken place.

The process consists of a dense palatal plate and a thinner buccal plate of compact bone. Within these bony plates, lies cancellous bone whose trabecular pattern supplies a supporting element arranged according to the chronological age of the specimen, (Pendleton²¹⁵).

Pendleton²¹⁵ showed that in middle life the trabecular framework is compact; while in those of more advanced age, the trabeculae are thin and the marrow spaces are greatly increased in size. This observation is supported by later work of Seipel.²⁴⁹

The alveolar mucosa is covered by stratified squamous epithelium. Beneath this layer is fibrous connective tissue which varies both in density and depth.

Generally over the crest of the ridge is dense fibrous connective tissue, except over the tuberosities where there is a considerable amount of loose connective tissue, (Kronfeld¹³⁷, Pendleton²¹⁵).

From the crest of the ridge extending up the buccal and labial surfaces, the tissue is less dense, providing some elasticity and mobility to the mucosa, (Pendleton²¹⁵).

CONDITION OF THE ORAL TISSUES PRIOR TO IMMEDIATE DENTURE CONSTRUCTION.GENERAL.

The condition of the teeth, periodontium, or possibly both, is the factor which induces a patient to seek this form of treatment.

The tissue changes associated with tooth extraction will be super-imposed on the existing oral status to a variable degree.

As Wiel³⁰⁹ has noted: "the degree of tissue resorption is not predictable with certainty, the procedures are different in each instance, and success depends mainly on the dentist's ability to evaluate the condition, and to determine which type of denture is indicated."

CONDITION OF THE TEETH.

The teeth may be grossly carious, rotated or protruding and for aesthetic reasons require removal.

The number of teeth present is variable and may be related to the age of the patient. A young patient is more likely to require a greater number of teeth to be extracted because of gross caries.

CONDITION OF THE PERIODONTIUM.

More frequently, the reason for tooth loss is the involvement of the supporting structures. In many cases, teeth have been retained when a chronic suppurative condition of the periodontal tissues suggested tooth extraction many years previously.

GENERAL EFFECTS.

The result of the retention of such infective sites on the general

health of the patient is indeterminate. However, Fish⁷⁸ has suggested the following channels by which tooth foci of infection may affect the general health:-

- 1) Direct spread of infection including the possibility of swallowing pus and inhaling infection, with consequent risk to the digestive and respiratory tracts.
- 2) A transient bacteraemia whenever hard food is masticated.
- 3) A constant absorption of toxic matter from the ulcerated surfaces at the gum margin into the general circulation.

LOCAL EFFECTS.

Rowell²³⁵ examined the tissues adjacent to 32 periodontal pockets and showed that the relation of the bony tissue is dependant on the degree of inflammatory response of the adjacent soft tissues. The marrow spaces and haversian canals adjacent to the inflammatory condition undergo a fibrous change with infiltration into the area of exudate cells.

Schei, Waerhaug, Lovdal and Arno²⁴⁰ in 737 adults, showed that loss of alveolar bone height increases with age and decreasing efficiency of oral hygiene. The resorption of the alveolar bone seems to occur primarily around the anterior teeth, then molars, bicuspids and finally cuspids.

Massler, Muhlemann and Schour¹⁶⁴ concluded from the examination of 350 young adult males, that a relationship could not be established between the degree of inflammation of the gingival papilla and level of the underlying alveolar bony crest.

TOOTH MOVEMENT.

The most common type of full maxillary immediate denture is

where the six anterior teeth, with possibly one or two posterior teeth, remain to be extracted. A variable number of lower natural antagonistic teeth are present, but loss of posterior contact has resulted in an overclosure of the vertical dimension with occlusal stress concentrated anteriorly.

Ramfjord and Kohler²²⁴ in six patients, studied such cases for the purpose of assessing the periodontal adaptation to a known functional increase in occlusal stress over a variable time interval, (85-198 days).

From block sections, which included gingival and periodontal structures attached to about one half of the root of the experimental tooth, they concluded that:-

- 1) A process of remodelling of the alveolar bone occurred which was an attempt to compensate for a labial movement of the teeth subsequent to the increased labial component of occlusal stress.
- 2) Apposition of bone was found on the labial aspect of the alveolar ridge and along the labial surface of the alveolar process. In four cases the labial bone plate was thick and made up of almost solid bone, but in two cases the labial alveolar process was perforated apically to the alveolar crest.
- 3) On the periodontal membrane side of the alveolar bone, there was evidence of alternating areas of resorption and repair with the resorption distinctly dominating over the new bone formation.
- 4) Where the periodontal membrane was under compression,



Fig. 4. Clinical appearance of functional increase in occlusal stress with loss of 224 posterior teeth. After Ramfjord and Kohler.



Fig. 4A. Histological section showing that the entire alveolar crest consists of newly formed bone. Root resorption extends into the dentine. Magnification X97.

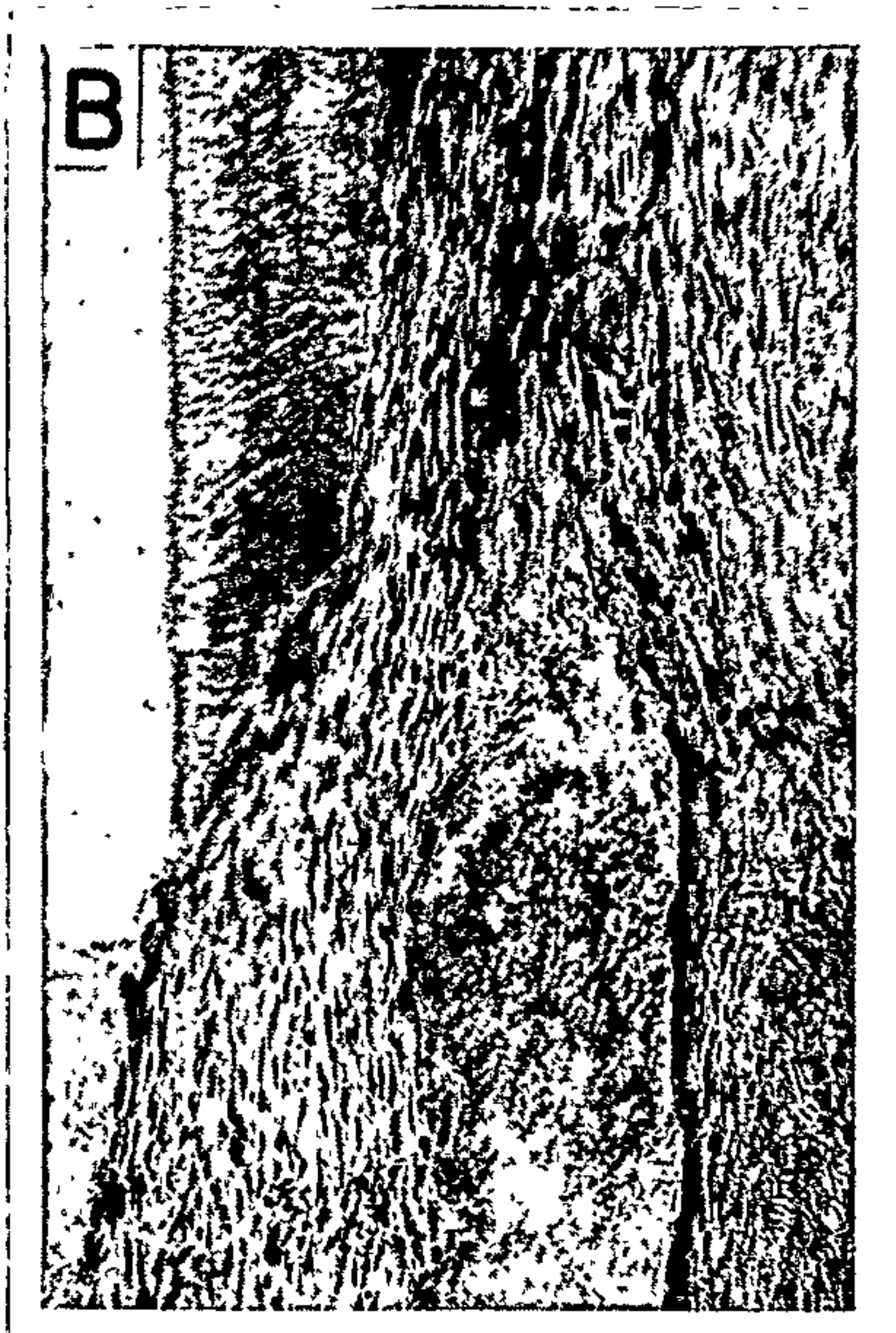


Fig. 4B. Higher magnification X280 showing compression of the periodontal membrane. The fibres are arranged parallel to the surface of the tooth and the alveolar bone, which is showing active resorption.

usually at the cervical area, a beginning hyalinisation was observed.

5) In areas where the labial plate was missing, the periodontal membrane assumed the morphological characteristics of periosteum. Attachments of muscle fibres into this area very closely resembled muscle attachments to regular periosteum.

Glickman and Wood⁹⁶ from microscopic studies of human autopsy material, showed that no morphological basis could be detected for the differentiation of the bone adjacent to the periodontal membrane from bone in relation to periosteal surfaces elsewhere in the body.

CONDITION OF THE EDENTULOUS ALVEOLAR PROCESS.

EFFECT OF FUNCTION.

With the loss of teeth, some degree of remoulding of the alveolar process in that area, occurs. From careful examination, the reconstituted alveolar process may serve as a guide to the resorption which can be anticipated on the insertion of a full immediate denture.

The questions which are raised by examination of the edentulous areas, are:-

1. Has a partial replacement been worn?
2. Has such a partial replacement provided functional stimulation to the underlying tissues or caused degenerative changes?
3. Has disuse atrophy resulted from not wearing any appliance?

MacWilliam¹⁷⁶ noted that: "functional adaptation of the alveolar process has been observed clinically under artificial appliances which are constructed in such a manner that physiological stimulation is applied."

Certainly any appliance which is inserted must aim at improving the oral conditions, or, at least maintaining existing conditions, (Page²¹²).

The problem of preserving the denture base and more specifically the alveolar bone was being examined by Pendleton and Glupker²¹⁶ and de Vam⁶⁴ and Page²¹² about the same time, 1935.

From clinical records, models and regular examinations of many patients, Pendleton and Glupker²¹⁶ conclude that:-

- 1) The regional reactions of the supporting tissues to full dentures are influenced by the unequal distribution of functional stresses resulting from acquired habits in mastication.
- 2) The soft tissues are the index to the changes displayed by the bone structures supporting the denture.
- 3) The preservation and functional adaptation of bone depends on the degree of mechanical action imposed on it - according to predominance of the periods of pressure and rest.
- 4) Areas of hyperplastic tissue indicate resorption of bone and are found in regions diametrically and diagonally opposed to areas subjected to "positive pressure."

The adaptation of bone structure to functional stresses is

CASE B.W. Female, aged 28 years, who had a full maxillary "near" immediate denture inserted 12 years previously and has not received further prosthetic treatment. The lower natural dentition consists of the following teeth R321|1234L, and posterior edentulous areas have not been restored. Consequently, the occlusion has been concentrated anteriorly with degeneration of the alveolar process from hyper-function.

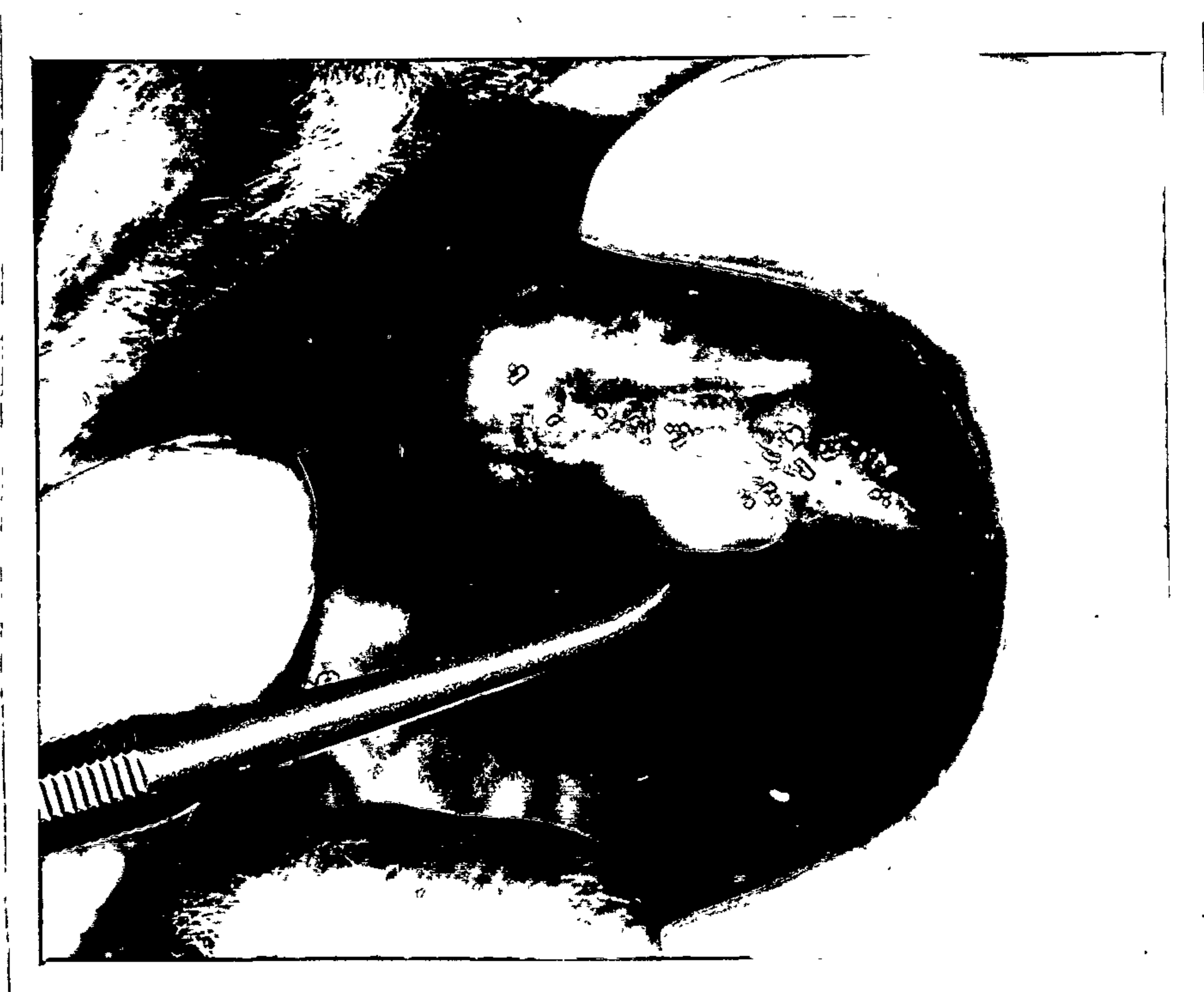


Fig. 5. A mobile flap of fibrous tissue can be observed on the alveolar crest, as well as an area of highly vascular granulation-type tissue along the labial and buccal surfaces of the alveolar process.

quantitative as well as qualitative with decreased function leading to a decrease in the bulk of the bone substance, (Orban²⁰⁷).

However, it has not yet been successfully explained as to why mechanical forces stimulate the apposition of bone and lack of function brings about bone resorption. Weinmann and Sicher³⁰⁵ suggest that mechanical and possibly vibratory stimuli probably result in new bone formation. Disuse atrophy is not then so much a direct loss of non-functional bone, but a lack of replacement of lost bone.

Generally bone tissue as such is resistant to tension and pressure (Weinmann and Sicher³⁰⁵), but it is generally agreed that alveolar bone particularly, is more counteractive in resisting compression.

However, difference of opinion exists as to whether dense or less dense bone will accept stress loads best or with least tendency towards atrophic changes, (Applegate⁹).

Froelich⁸⁴ supports Pendleton²¹⁴ in his assessment of areas of stress distribution for support of a maxillary denture. He describes a "hypoplastic atrophy" which occurs to an edentulous alveolar process which has not borne a denture.

Campbell³⁷ could not support the above investigators, following a quantitative survey of edentulous persons who had been institutionalised for many years. In measuring the alveolar ridges in 70 patients, 38 patients having worn dentures for many years and 31 never having worn an appliance, he showed a significant reduction in the labio-lingual dimension of the maxillary alveolar

process in the denture-wearing group. No apparent reduction in the vertical dimension of the alveolar process could be observed.

CONSERVATION OF THE ALVEOLAR PROCESS.

de Van⁶⁴ has analysed the full maxillary denture bearing area for stress counter-action and suggested modifications to the denture to reduce the torsional forces imposed. These modifications include:-

1. Changes in the tooth form and position.
2. Meticulous attention to occlusal balance.

A subsequent paper by de Van⁶⁵ written twenty-seven years later, reiterates his observations on stress counteraction of the alveolar bone in relation to partial denture construction.

Smedley²⁶² suggests that bone mineralisation and denture imbalance or trauma are of more significance to the maintenance of satisfactory ridge formation for denture support than the age or previous periodontal condition of the patient.

Shearer²⁵² and Schlosser²⁴² agree that traumatic occlusion of the dentures is one of the greatest factors in the destruction of the alveolar arch. Balanced occlusion minimises the stress to the supporting tissues and prolongs the service life of the dentures.

Page²¹² while appreciating the value of the mechanical approach of denture construction towards conservation of the alveolar process, suggests that the systemic condition of the patient must also receive attention. Blood tests and dietary analyses are routine procedures.

Certainly as Dittmer⁶⁸ observed, "the functional efficiency and comfort that can be obtained in any immediate denture case is in direct proportion to the supporting hard and soft tissues"

Dawborn⁵⁷ suggests that the stability of an immediate denture is due to the reduced resorption of the alveolus as a result of pressure stimulation.

CONCEPT OF "BONE FACTOR."

The concept of a bone factor was elaborated by Glickman and Wood⁹⁶ and the term subsequently coined by Glickman.⁹⁴

In various studies on rats in which nutritional deficiencies and local periodontal reactions were induced, a concept of alveolar bone physiology emerged, (Glickman^{93, 94}).

As stated by Glickman⁹⁴ -

"Normally the height of alveolar bone is maintained by a constant microscopic equilibrium between bone formation and bone resorption. This physiological equilibrium is regulated by both local and systemic factors the severity of bone loss which occurs as the result of local factors is not determined by their duration and severity alone. The response of alveolar bone to local destructive influences is subject to the additional regulation of the individual systemic background

Because the status of the individual systemic background cannot always be catagorised by the extremes of 'health' or 'disease,' its 'formative' or 'destructive' influence upon alveolar bone is of necessity characterised by subtle variations rather than by opposite extremes"

Baume¹⁶ in a radiographic, biometric and histologic study of the developing dentition of 44 rhesus monkeys, showed that the tooth and investing bone constitute a developmental entity. Any systemic disturbance will influence the alveolar formation at that particular

time, eventually leading to a lasting constitutional inferiority of the respective alveolar process.

Functional disturbance during development, (Baume,¹⁶ Horowitz and Shapiro¹¹²) will also retard alveolar growth, leaving the supporting bone in an immature state, prone to precocious degeneration.

Horowitz and Shapiro¹¹² describe a disuse atrophy occurring in rats following sectioning of the temporalis, masseter and digastric (ant. belly) muscles. The radiographic picture was typically osteoporotic with a reduced trabecular pattern.

CONCLUSION:

From the fore-going investigations, it may be concluded that a well-balanced systemic background, as well as adequate functional stimulation, is necessary for the formation of a completely matured and resistant alveolar bone.

RADIOGRAPHIC EXAMINATION.

Apart from clinical examination, the main accessory diagnostic aid to assess the character of the alveolar process, dentulous or edentulous, is by X-ray.

Goldman, Millsop and Brenman⁹⁷ showed on human maxillae that the buccal and lingual alveolar plates are connected with the lamina dura in the crestal regions. There is no spongy bone in this region from a bucco-lingual direction, but spongy bone is present mesio-distally from the lamina dura of one tooth to the lamina dura of the adjacent tooth.

Radiographically the consequence of this investigation showed that:-

"the lamina dura registration resulted from the presence of dense bone extending the full buccolingual width of the tooth. It is the quantity, not the character, of bone that determines the typical radiographic findings. This also holds true for the registration of the alveolar crest,"

Patur²¹³ suggests that a long cone paralleling projection technique will reduce the errors inherent to normal X-ray techniques and overcome the difficulties of interpreting radiographs for evaluating the position of the marginal alveolar bone and destructive bone patterns.

Theilade²⁸² showed in 39 dried human skeletal specimens, that a serious underestimation of bone loss due to periodontal disease occurred. Differentiation between buccal and lingual alveolar plates of bone could not be made and resulted in a false assessment of the bone height.

Applegate⁹ observed that the density of bone, based on radiographic evidence, is not without error. Changing one or more of the following factors will alter the film appearance so as to result in a different interpretation of the bone density portrayed: time of exposure, target - film distance, angulation, developing and fixing times, temperature or technique.

Undoubtedly however, alveolar bone character, height or loss is difficult to evaluate without the use of radiographs, an important diagnostic accessory.

CONDITIONING APPLIANCES.

The possibility of stimulating an unused residual alveolus, by mild exercise, to a condition in which it will have adequate supportive

ability is suggested by Applegate,⁹ for partial prostheses.

The application equally pertains to the patient about to be rendered edentulous with full immediate dentures.

Smith²⁶⁴ has offered supportive radio-graphic evidence that previously unused bone can be reconditioned by mild work stimulation.

His technique standardises head position, target-film distance, angulation and exposure times for patients who have had non-masticatory acrylic plates inserted as exercisers.

Gardner⁸⁵ suggests that where alveolar bone has not been in use, bone pain or discomfort may be experienced as well as muscle pain, if function is restored too rapidly. Certainly, restoration to function must be within the limits of tissue tolerance, (Applegate⁹).

The author has used conditioning appliances satisfactorily in a patient requiring both maxillary and mandibular full immediate dentures. The advantages noted were:-

- 1) Restoration of a reduced vertical dimension from loss of posterior occlusal contact through extractions of lower molars and gross carious lesions - a mandibular prognathism had resulted.
- 2) Difficulties of speech associated with the additional bulk of denture bases, were minimised prior to the insertion of the full immediate dentures.
- 3) Stimulation and protection was afforded to the hyperaemic gingiva. As a result of gross caries, stimulation could not be provided either by chewing of food or tooth-brushing

CASE P.P. Female, aged 19 years at time of insertion of full maxillary and mandibular immediate dentures, involving the extraction of the following teeth R 87 54321 | 12345 78 L.
321 | 12345



Fig. 6. Poor oral hygiene associated with extensive carious lesions and hyperaemic gingivae can be seen. Loss of posterior tooth contact had produced a mandibular prognathism as a result of the reduced vertical dimension.

CASE P.P.

Fig. 7. Conditioning appliances inserted and worn for a period of twelve weeks prior to the insertion of immediate dentures. The adjustment of the patient to wearing these appliances was rapid and produced a satisfactory mental approach to the subsequent insertion of full dentures.

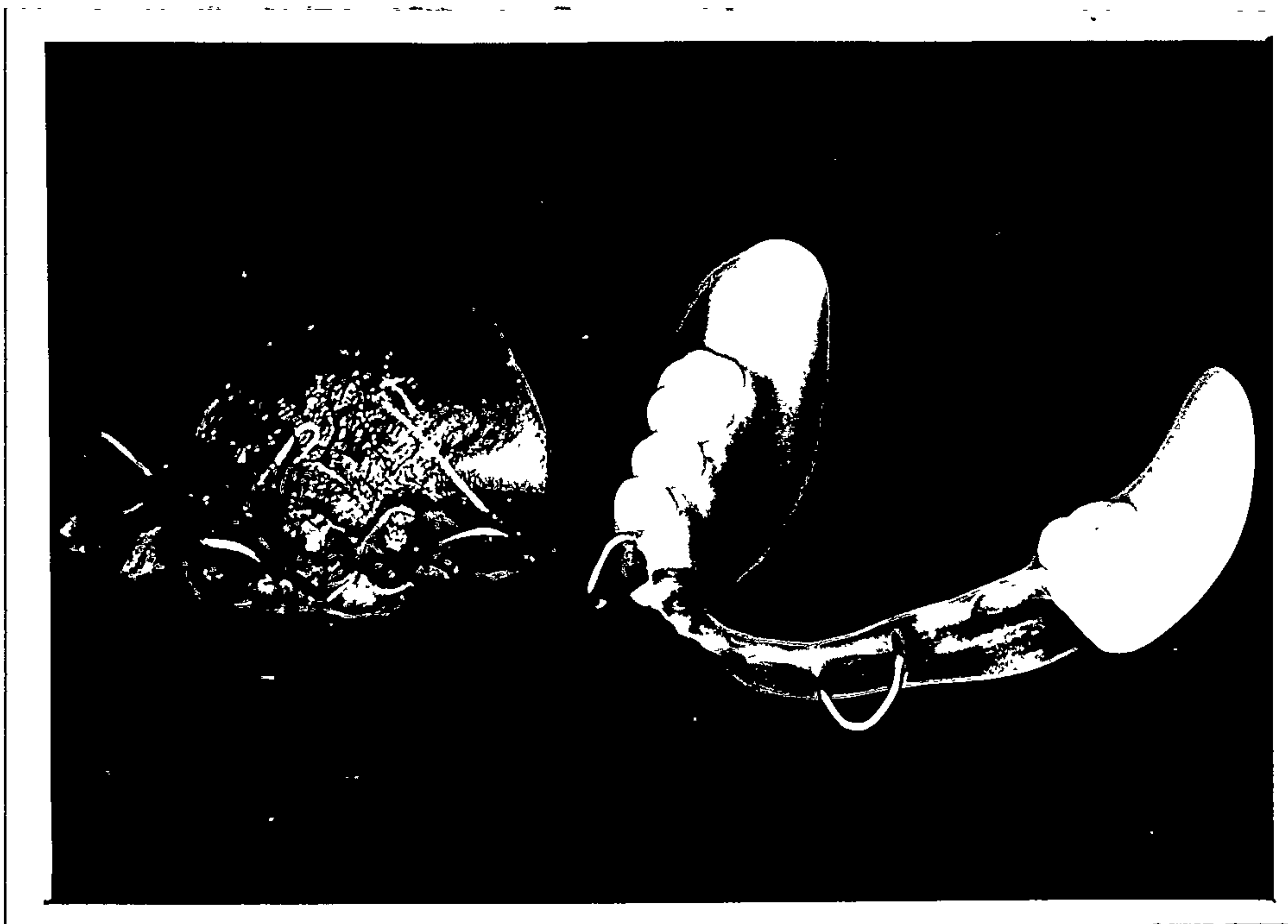


Fig. 8. Conditioning appliances used by case P.P., which consist of a clear acrylic maxillary base and mandibular partial denture, with restoration of the vertical dimension established over the entire occlusal surfaces.

POSTERIOR TOOTH EXTRACTION.

Where a variable number of posterior teeth are present, as well as the anteriors, the question arises as to whether these posterior teeth should be extracted with a short healing period before construction of the full immediate denture.

CONSERVATIVE.

The majority of authors favour posterior extraction with a healing period of from 3 - 8 weeks, (Harris,¹⁰⁴ Jordan,¹²⁴ Smith,²⁶⁵ Axelbrand,¹³ Schweitzer,^{245, 246, 247} Hughes,¹¹⁹ Schlosser,^{241, 242} Garn,⁸⁷ Martin,¹⁶⁰ Lieberman¹⁴⁴ and Gimson⁹²).

The principal advantage claimed is that a stable base is provided on which the denture may be supported and thereby provide greater comfort and efficiency to the patient as well as increasing the service life of the denture.

Matson¹⁶⁵ constructs the denture and removes the posterior teeth one week before completing the extractions and inserting the denture.

FULL CLEARANCE.

de Van,⁶³ Frahm,⁸² Van der Ven²⁹³ and Windecker et al.³¹¹ agree that extraction during the smallest number of visits is generally preferable with consideration to the patient's psyche.

The other advantages claimed for full tooth clearance at the time of denture insertion are:-

- 1) Social in that the patient does not suffer an unaesthetic period from missing teeth.
- 2) The tongue does not alter in shape or increase in size with possibly resultant speech difficulties.

3) Chewing efficiency is maintained.

Frahm⁸² suggests that the denture can be seated on a base which will allow uniform pressure during function and consequently undergo the same amount of resorption throughout its entire area.

However, as mentioned by Neill,¹⁹¹ the main disadvantage is the rapid tissue changes which occur and result in the denture having only a temporary function.

Constant maintenance is required and Windecker et al.³¹¹ are prepared to rebase or reline the denture within a very short length of time.

CHAPTER V.METHODS AVAILABLE FOR IMMEDIATE REPLACEMENT OF ANTERIOR TEETH.PRE-IMMEDIATE SURGICAL PROCEDURES.

In some instances, it is advisable to carry out certain surgical procedures before the construction of the immediate denture. The indications are:-

- 1) Pendulous tuberosities of the maxilla with gross disharmony between opposing alveolar ridges and reduced intermaxillary space, (Hayward and Thompson,¹⁰⁸ Bourgoyne²⁶ and Aseltine).¹⁰

The tuberosities may be of the bulbous bony type or of fibrous tissue, (Molt¹⁷²). Submucosal fibrous hyperplasia may be contoured by excision and thinning, (Hayward and Thompson¹⁰⁸).

Reduction of the alveolar process in this region, however, is limited by the floor of the maxillary sinus. Where this difficulty arises, Hayward and Thompson¹⁰⁸ suggest that reduction of the opposing retromolar pad may be necessary.

- 2) Tori palatini which may contribute greatly to denture instability as normal healing resorption proceeds, (Molt,¹⁷² Maison,¹⁵⁶ Wood³¹³ and Suddarth²⁷⁰).
- 3) Irregular ridge shapes and rough bone margins following previous extractions, (26, 313).
- 4) Razor edged ridges showing advanced resorption, (313, 156).
- 5) Hypertrophied tissue flaps, (172, 156, 313, 26, 10).
- 6) Abnormal frena and muscle attachments, (156, 10).
- 7) Elimination of neoplasms and other pathological sites, (108).
- 8) Removal of root fragments, impacted and supernumerary teeth, (26).

FORCEPS EXTRACTION.

As has been mentioned, usually the anterior teeth only remain to be extracted. Whether these teeth may be removed by normal forceps extraction or require surgical methods, with some degree of alveolar bone removal, will depend on the individual case.

The method of choice will only be decided following evaluation of the data from a complete clinical and radiographic examination. Modifications to the denture base may then be made during construction.

Generally, the greater number of full maxillary immediate dentures are inserted after the remaining teeth have been removed by normal forceps extraction.

Tooth removal with forceps is brought about by the application of force in a series of movements, variously described as thrusting, rotating, levering. These movements should logically be predetermined as to their nature, direction and sequence from a knowledge of the root structures and the alveolus of the particular tooth involved. Designed as they are to remove the tooth in toto, the applied forces result in a stripping of epithelium from the tooth and a tearing of the periodontal fibres in some part of their length; this latter depending on the nature and direction of the forces applied, (Radden²²³).

ARTIFICIAL ROOTS EXTENDING INTO THE SOCKETS.

In a socketed case, the close adaptation of the margins to the tissues must be maintained through the artificial roots making contact with the mucosa lining, the residual sockets and the apposition of the soft tissues of the papilla with the denture between the artificial teeth.

CASE Y.H. Female, aged 22 years at time of insertion of full maxillary and partial mandibular immediate dentures, involving the extraction of the following teeth:

R 321|123 L.
1

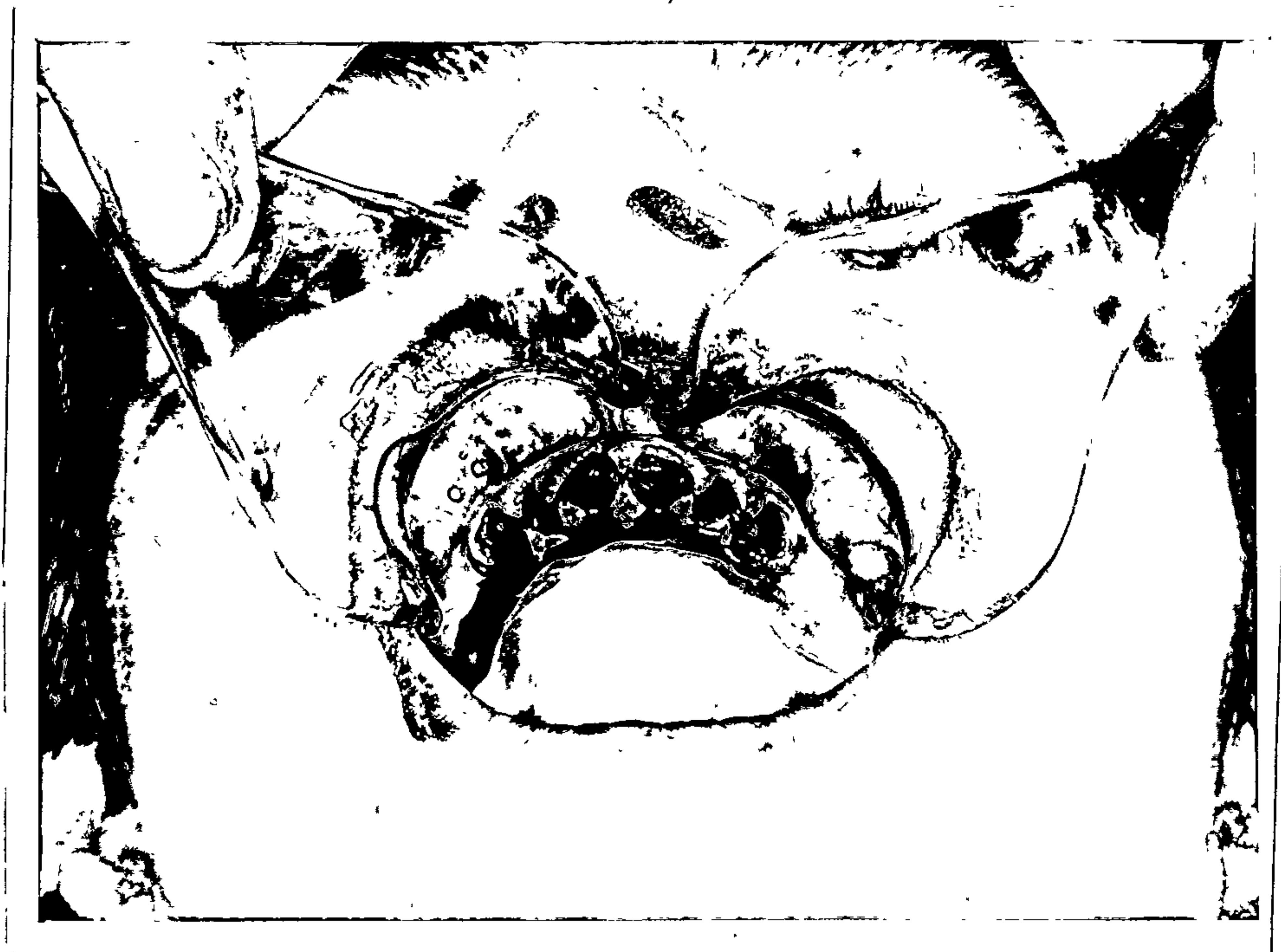


Fig. 9. Appearance of alveolar sockets following forceps extraction of teeth using local anaesthesia, (2% Zylocaine with 1:50,000 epinephrine).

Laceration to the epithelial margins may be seen with split interdental papilla and exposure of alveolar bony crest of maxillary left central and canine.

For this purpose, roots are added to the artificial teeth which enter the first 3-5mms. of the socket on the labial aspect but have a concave upper surface from here to the palatal margin of the socket.

This procedure is based on the assumption that the socket will become filled with new bone and the labial plate gradually resorb until the teeth, with their root extensions, assume a gum fit.

Neill¹⁹¹ claims that although this is the ideal result which may be expected, rarely does such a condition occur.

ADVANTAGES.

Schweitzer^{245, 246, 247} and Gimson⁹² claim that surgical reduction of the labial alveolar plate may be prevented by a socketing preparation. Presumably the normal resorptive processes will reduce any excessive prominence of the anterior alveolus.

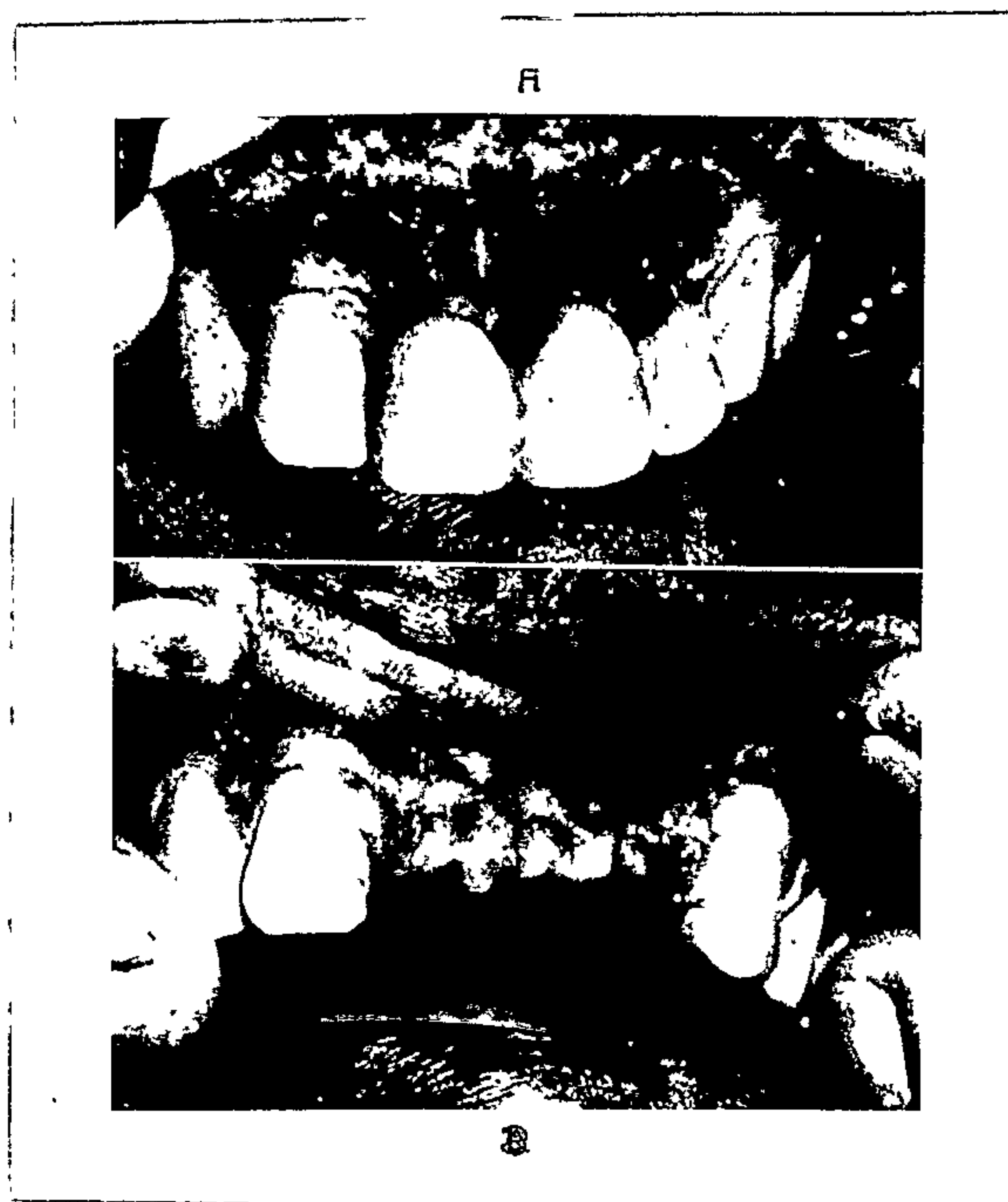
Neill¹⁹¹ mentions the bulbous nature of the canine prominence which sometimes interferes with the extension of a denture flange to the full depth of the sulcus.

Gimson⁹² prefers the more natural appearance where the teeth "appear to grow from the gum."

Normal lip contour is maintained with usual movements undisturbed, (Gimson⁹²).

DISADVANTAGES.

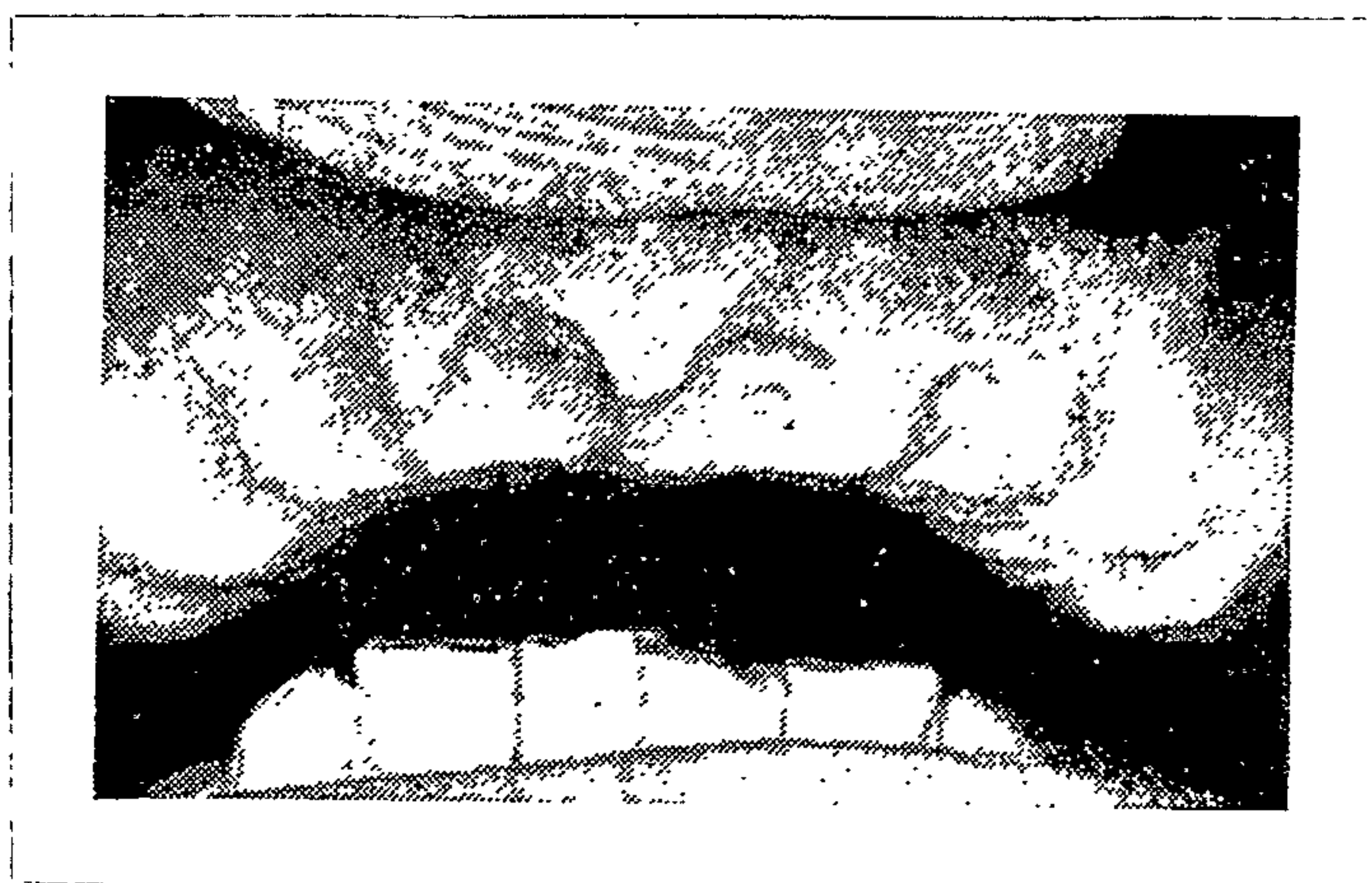
To assess the degree of resorption which will occur is arbitrary, and either over-extension or under-extension of the depth of socketing will produce unfavourable results.



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After Lam.

Fig. 10. Excessive resorption of a residual ridge as a result of failure to institute corrective procedures during the first month following insertion of the immediate denture.

- A. Excessive socketing with resorption away from the cervical ends of the teeth.
- B. The tissue is severely traumatised.



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After Neill.

Fig. 11. Effect of over extended artificial roots on the alveolar process.

OVER-EXTENSION OF SOCKET PREPARATIONS.

As a result of over-extension of the root projection, the resulting contour of the labial surface of the alveolar ridge is unsuitable to support a labial flange and surgical remodelling of the bone becomes necessary, (Neill¹⁹¹).

Lam¹³⁹ measured the tissue changes occurring with 3 patients in whom partial immediate dentures with socketed anteriors had been inserted. He showed that excessive socketing and failure to institute corrective procedures, inhibited the healing processes in the socket and caused excessive resorption of the alveolar ridges.

UNDER-EXTENSION OF SOCKET PREPARATIONS.

Where the root projections have been under-extended, an unaesthetic space rapidly develops between the artificial teeth and the mucosa.

Terrell²⁸¹ suggests a thin flange extension, approximately 5-10mms. beyond the gingival margin, to overcome this aesthetic factor. Reline procedures should be effected within six weeks.

SOCKETING PREPARATION WITH RETENTIVE "WING" EXTENSIONS.

As described by Neill,¹⁹¹ "wing" extensions which project forward from the buccal flanges, are incorporated in a socketed immediate denture.

The advantages claimed for these projections are:-

- 1) They provide indirect retention by preventing distal displacement of the denture.
- 2) Prevent or reduce vertical displacement of the denture anteriorly by engaging an area which is undercut relative



Fig. 12. Retentive "Wing" extensions added to a gum-fitted immediate denture.

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to a vertical axis of withdrawal.

- 3) Resistance to lateral stresses applied to the denture.

TOOTH EXTRACTION WITH SURGICAL REDUCTION OF THE ALVEOLAR PROCESS.

GENERAL.

Numerous terms have been introduced to describe the procedure of tooth extraction with surgical reduction of the alveolar process in immediate denture construction. Such terms as alveolotomy, alveolectomy and alveoloplasty are common in the literature, whereas alveolomereotomy is a term which has also been used.

The concept of moulding the alveolar process by surgical means has been practised extensively, with the principal objective of providing suitable support for the construction and wearing of dentures. In many instances, patients so treated have been edentulous for a variable length of time.

Therefore, the terms to be described overlap, to some extent, with those used in oral surgery generally.

DEFINITION OF THE TERMS ALVEOLOTOMY, ALVEOLECTOMY AND ALVEOLOPLASTY.

Some confusion exists among authors as to the application of these terms to the degree of alveolar remodelling which they practise.

This confusion of terms has no doubt arisen from:-

- 1) The strict translation of the Greek derivatives ektome¹ and tome² meaning excision and incision respectively, (Stedman²⁶⁹).
- 2) The use of the terms pulpectomy and pulpotomy in endodontic procedures where complete and partial removal of the pulpal contents are implied respectively.

Blackiston²⁴ provides the following definitions:-

Alveolotomy - incision into a dental alveolus.

Alveolectomy - surgical removal of part of the alveolar process of the upper or lower jaw.

Alveoloplasty - surgical alteration of the shape or size of the alveolar ridge to aid in the construction of prosthetic appliances.

Hayward and Thompson¹⁰⁸ appreciate that the literal connotation of the term alveolectomy means excision of the alveolar process. However, they suggest that in its practical usage, the term designates the preparation of alveolar ridges for the reception of dentures.

Van der Ven²⁹³ and Neill¹⁹¹ prefer to use the term alveolotomy. With procedures involving partial resection of the alveolar process, the terms "extent of alveolotomy" and "radical alveolotomy" are considered to be more appropriate.

Bourgoyne²⁶ and Gores, Royer and Mann⁹⁹ prefer the term alveoloplasty, with the emphasis on the proper preparation of the alveolar ridges FOR DENTURES, rather than as a routine oral surgery procedure.

The extent and severity of alveoloplasty are graded by Gores et al.⁹⁹ as follows:-

Grade 1. Removal of teeth. No cutting of alveolar bone.

No alveolar muco-periosteal flaps.

Grade 2. Removal of teeth. Removal of interproximal bone from alveolar crests, without extensive mucoperiosteal flaps.

Grade 3. Removal of teeth. Moderate removal of alveolar bone from crests and from buccal or labial aspects (either or both) with extensive mucoperiosteal flaps.

Grade 4. Removal of teeth. Extensive removal of alveolar bone from crests and from buccal or labial aspects (either or both) with extensive mucoperiosteal flaps.

As an example of the confusion which exists regarding the use of the terms alveolectomy etc. the following descriptions are presented:-

Allen⁵, "Prosthetic alveolectomy then aims at stabilising the ridges by effecting a surgical removal of that precise amount of bone which would be absorbed during the healing process."

Atterbury,¹² "alveolectomy consists of removal of the teeth, incision, and reflection of the covering mucoperiosteum, and surgical excision of part of the alveolar process to produce a foundation on which a more satisfactory denture can be constructed."

The definition of alveolectomy by Allen⁵ is, in effect, precisely what Van der Ven²⁹³ wishes to imply by the term alveolotomy.

For simplification, therefore, in reviewing the literature of the surgical procedures involving the anterior alveolar process in immediate denture construction, the terms alveolotomy and alveolectomy may be defined as follows:-

Alveolotomy - involves the removal of teeth and the smoothing over and rounding of interproximal bone at the alveolar crests and labial cervical areas where prominent.

The mucoperiosteal flap is not extensive and does not require elevation beyond the mucogingival junction.

Alveolectomy - involves the removal of teeth and moderate to extensive removal of alveolar bone from the alveolar crests and from the labial cortical plate - reduction in both height and width of the alveolar process is implied.

In some cases, removal of bone from the palatine cortical plate is necessary.

Extensive elevation of the mucoperiosteal flap is required and some reduction of this flap may be necessary on repositioning. The degree of reduction will depend on the amount of alveolar bone which has been removed.

INDICATIONS FOR ALVEOLOTOMY AND ALVEOLECTOMY.

The indications for both procedures are essentially the same, the difference being one of degree only.

AESTHETIC.

PSYCHOLOGICAL

Prominent anterior teeth are aesthetically unpleasing and may have an adverse psychological effect on the patient, (Molt,¹⁷¹ Dittmer,⁶⁸ Light,¹⁴⁵ Bourgoyne²⁶ and Wood³¹³).

SKELETAL.

A protrusion of the maxillary anterior arch may be a skeletal development. As mentioned by Hayward and Thompson,¹⁰⁸ extreme Class II malocclusion and relative mandibular micrognathism requires special treatment planning.

EXTREME OVERBITE.

An extreme overbite with high upper lip attachments is associated with abnormal length of the maxillary alveolar process and may therefore require reduction, (Hayward and Thompson¹⁰⁸).

LOSS OF POSTERIOR TOOTH CONTACT.

Labioversion of the maxillary anterior teeth through loss of posterior tooth contact and increased occlusal loading has been fully examined by Ramfjord and Kohler²²⁴ from

the periodontal application.

FUNCTION.

Replacement of the artificial teeth in the same position as the natural teeth, may result in a denture which is functionally unstable.

However, rearrangement of the artificial teeth may be limited by the alveolar ridge, to which some modification must be made to allow satisfactory denture construction.

ADVANTAGES OF ALVEOLOTOMY AND ALVEOLECTOMY.

Allen⁵ claims that surgical intervention on the alveolar process results in a more retentive and efficient denture through the elimination or reduction of undercut area.

DISADVANTAGES OF ALVEOLOTOMY AND ALVEOLECTOMY.

As has been summarized in the historical development of immediate denture construction, the general trend of thought has swung away from routine surgical intervention on the alveolar process.

Jordan¹²⁴ states that: "extreme alveolectomy in preparation for full denture construction is no longer considered good dental practice."

Frahm⁸² feels that: "Conservation of the edentate alveolar process should be given first consideration, allowing nature to do what she can in the building of a firm, healthy base. No attempt should be made to simulate natural resorption of the alveolus."

Hughes¹²⁰ is of the opinion that: "There is no possibility of producing a permanent alveolar ridge contour by means of surgery."

The main reason for this conservative surgical approach has

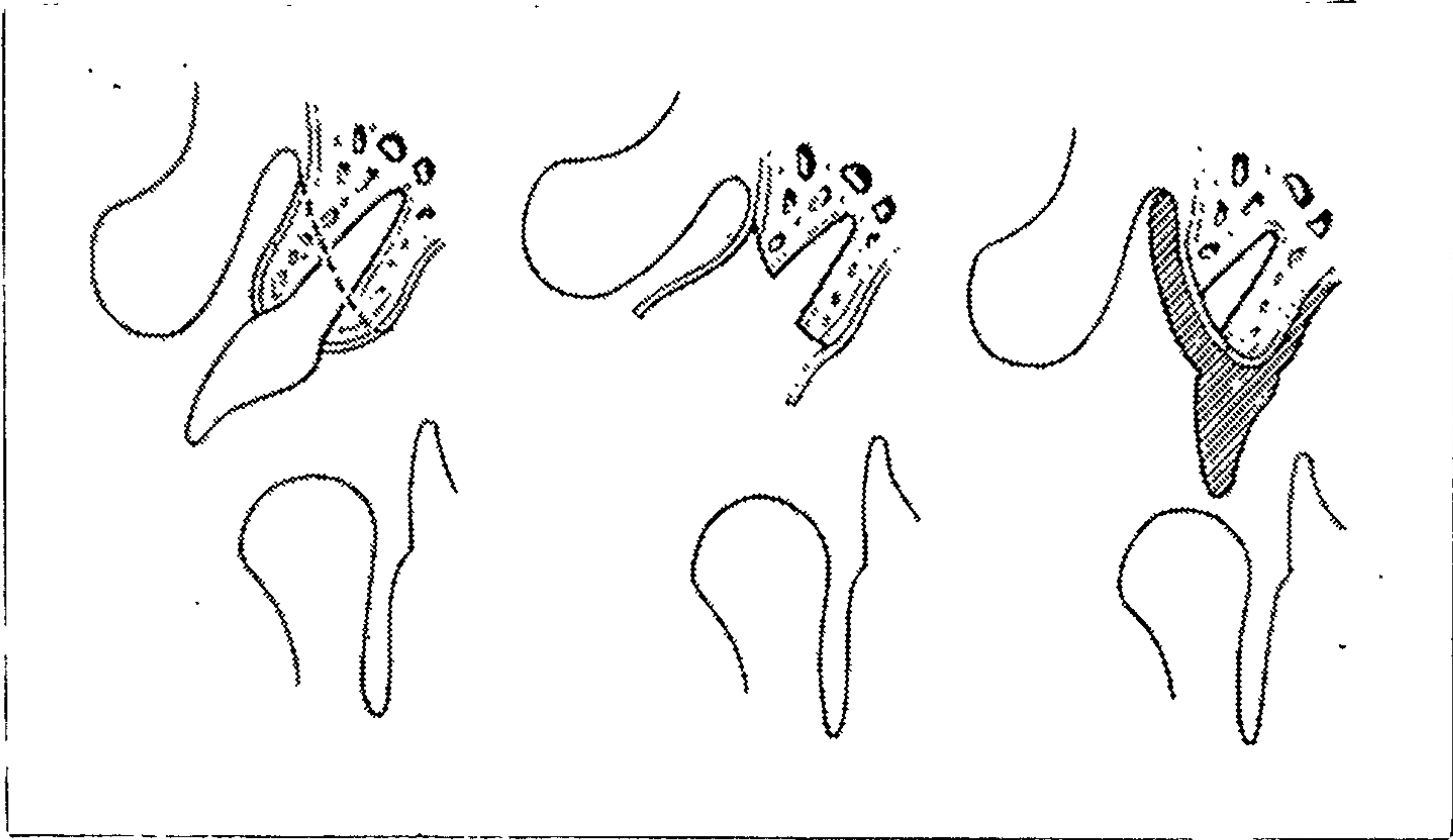


Fig. 13. Diagram of alveolectomy technique for reduction of a maxillary prognathism.

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been the subsequent resorption which takes place. It has been generally agreed upon by authors, (Frahm,⁸¹ Maison,¹⁵⁶ Craddock,⁵³ Johnson,¹²² Schweitzer^{245, 246, 247} and MacWilliam¹⁷⁶) that with removal of the labial cortical plate, the cancellous bone is exposed to the stress of occlusion and consequently resorbs rapidly.

As mentioned by Page²¹²: "As much healthy process must be retained as possible - bone cannot be developed to a greater height than the surrounding periosteum can be healthfully supported."

Schweitzer^{245, 246, 247} is of the opinion that "too much bone is removed in almost every case, no matter how careful the operator tries to be."

Certainly any corrective surgery must be carried out only after careful evaluation of articulated study models, radiographs and a pre-operative knowledge of the exact prosthetic requirements, (Hayward and Thompson¹⁰⁸).

Conservative and properly executed surgical procedures are of inestimable value to the patient and a distinct aid to the prosthodontist, (Suddarth²⁷⁰).

METHOD OF OPERATION FOR ALVEOLOTOMY AND ALVEOLECTOMY.

The operation consists of the reflection of mucoperiosteum in the area where the surgery is to be performed. The teeth are removed and the required degree of alveolar bone with rongeur forceps, chisels or burs with a final smoothing using a bone file. The approximation of labial and lingual periosteum follows, together with the necessary suturing, (Wood³¹³).

INTRA-SEPTAL ALVEOLOTOMY.

The term, intra-septal alveolotomy, is used to designate a technique perfected by Dean⁵⁸ in 1916-17.

This technique allows the reduction in prominence of the labial and buccal aspect of the alveolar process to facilitate the reception of dentures, without disturbing the muscle attachments or periosteum and without removing the cortical plate of bone.

Essentially, the operation consists of reduction in circumference of the labial-buccal arch of the alveolar process by removing a narrow inverted V section of bone from the labial plate of the cuspid socket, extending almost its full length.

Sinfield²⁶¹ claims to have used this technique successfully in 300 patients, with a subsequent denture relining procedure required in only 5% of these patients.

ADVANTAGES.

The advantages claimed for the intra-septal alveolotomy technique are, (Sinfield²⁶¹):-

- 1) The natural appearance of the lower one third of the face is retained. Through collapse of the anterior ridge, a labial flange may be used in the denture without excessive bulk under the lip.
- 2) The tissues may be moulded to conform to the denture.
- 3) The cortical plate of the alveolar process is retained to form a perfectly rounded ridge which assures satisfactory denture support.

DISADVANTAGES.

Hayward and Thompson¹⁰⁸ consider that, despite the conservation of cortical bone, the reduction in ridge width makes the intra-septal alveolotomy technique questionable. In view of future prosthetic requirements, the maintenance of ridge width has equal, or possibly

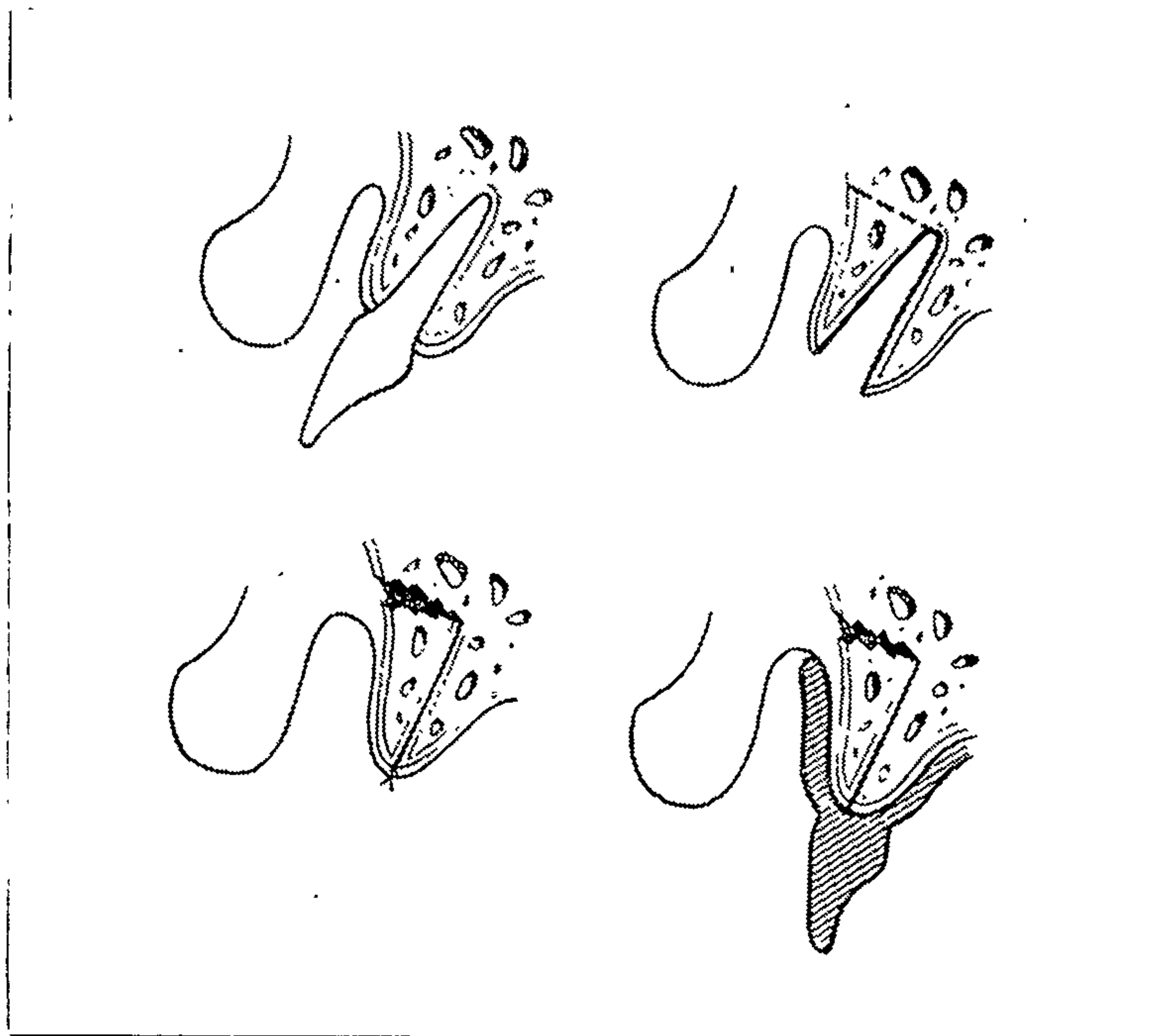


Fig. 14. Diagram of the technique of intra-septal alveolotomy.

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METHOD OF OPERATION.

Sinfield,²⁶¹ Wood³¹³ and Neill¹⁹¹ have employed similar techniques to that originally described by Dean,⁵⁸ a summary of which follows:-

- 1) The teeth are removed by normal forceps extraction with the maximum of care being taken not to traumatise the soft tissues or fracture the labial or buccal cortical plate of bone.
- 2) Incisions to the intra-septal soft tissues are made palatally to allow the removal of the intra-septal bone using rongeur forceps. These bony septa are removed the full length of the tooth socket, the lines of excision following the direction of the socket walls.
- 3) The labial and buccal cortical plates are fractured towards the palate, by placing a thin flat chisel in the tooth socket with the bevel close to the apex.
- 4) All exposed bony surfaces are smoothed over by filing and any pathological areas curetted.
- 5) The periosteum is carefully elevated over the canine socket to allow an inverted V section, in labial bone only, to be removed with rongeur forceps.
- 6) Thumb and finger pressure is applied to the labial and buccal bone plates to effect reduction in labial-buccal arch circumference and moulding of the ridge to the desired form.
- 7) The soft tissues are sutured whenever necessary.

OTHER SURGICAL METHODS.

Helmore¹¹⁰ describes the normal alveolectomy technique as well

as the following method:-

- 1) A horizontal incision is made 2-3mms. below the gingival margin and that section of mucous membrane removed entirely.
- 2) The teeth are extracted and a mucoperiosteal flap raised beyond the line of incision of the mucosa.
- 3) The margins of the tooth sockets are rounded with rongeurs and bone file.
- 4) The mucoperiosteal flap is repositioned and sutured if necessary.

Wagman²⁹⁷ describes a surgical technique which does not require the raising of a flap.

After clinical examination, he notes the amount of alveolar reduction required on a cast and then transfers this measurement to the mouth with calipers.

The teeth are removed and the soft and hard tissues are trimmed back to this marked line.

No attempt is made to cover any bone which is cut or exposed, reliance being placed on the formation of a healthy blood clot with the denture acting as a stent.

CAST PREPARATION.

To allow the tissue surface of the immediate denture to reproduce the proposed shape of the alveolar process after either forceps extraction or surgical procedures, the model or cast must be trimmed accordingly.

The degree of trimming depends on the configuration of the bone and, to a lesser degree, on the thickness of the submucous tissue.

As Van der Ven²⁹³ has noted:-

"When the alveolar process is healthy so that the bony ridge of the alveolus still almost entirely encloses the roots, and the mucosa is firm, the gingival margin of the gums will move very little after the extraction."

However, the inaccuracies can be most significant, when a uniform method of cast trimming is employed. Standard²⁶⁸ suggests a uniform reduction to the labial gingival margin of 2mms. in both width and depth, with subsequent rounding of the labial alveolar process.

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Neill however, feels that the soft tissue outline shown upon the model prior to extraction of the teeth bears little relationship to the contour of these tissues after extraction. The reasons for the inaccuracies presented by examination with a graduated probe of the pockets surrounding the teeth are:-

- 1) The depth of the pocket will vary.
- 2) The bottom of the pocket does not correspond with the margin of the supporting bone.
- 3) The information obtained does not indicate the position of the bony support to the interdental papilla.

Van der Ven²⁹³ is in agreement with Neill¹⁹¹ and suggests the following method for estimating the future state of periodontally involved tissues.

Measurement of the depth of the gingival sulcus is made using a straight probe which has been fitted with a millimetre scale. The measurement is noted around each tooth and recorded on a tooth-chart.

A pencil line may then be drawn along the necks of the teeth on the cast using these measurements. The pencil line therefore indicates

approximately where the bony socket ends and trimming of the cast is facilitated by this means.

CLEAR GUIDE.

The use of a clear base or template during surgical procedures, is advised by most authors, (Sears,²⁴⁸ Craddock,⁵³ Jordan,¹²⁴ Harris,¹⁰⁴ Dittmer⁶⁸ and Neill¹⁹¹).

At intervals during the operation, the soft tissue flaps are replaced and the clear base inserted and pressed into position. Where more bone needs to be removed, the tissues are seen to blanch through the transparent base, irrespective of the degree of bleeding, (Neill¹⁹¹).

Such bases may be constructed of thermoplastic celluloid sheet⁶⁸,¹²⁴,²⁴⁸ or of acrylic resin,²⁷⁴,¹⁹¹,¹²⁴.

Duplication of the denture cast after it has been trimmed the required amount, provides the cast on which the clear base may be constructed. By this means, the tissue-fitting surfaces of both the immediate denture and the clear base correspond exactly and any difficulty in fitting the denture is eliminated.

LABIAL FLANGE.

In all instances, other than where the anterior teeth have been socketed, a labial flange is used for full maxillary immediate dentures.

With forceps extraction of the anterior teeth, the use of a labial flange or socketing is dependant upon the particular requirements of the case. However, any surgical procedures imply that a labial flange should be incorporated in the denture.

ADVANTAGES.

Retention - Van der Ven²⁹³ is of the opinion that the retention of a prosthesis with a flange is considerably better than of a

CASE P.P.

Fig. 15. Clear acrylic maxillary template positioned following tooth extraction, and showing an area of compression, (mid-picture), where further removal of labial bone is indicated.

prosthesis without a labial flange.

PRESERVATION OF RIDGE FORM.

Smith,²⁶⁵ Hughes,¹¹⁹ Axelband,¹³ Craddock⁵³ and Standard²⁶⁸ clinically observed that there is regeneration of bone and development of the ridge area to the contours of a properly adapted immediate denture. However as noted by Standard²⁶⁸ -"To accomplish this successfully, there must be complete tissue coverage by the immediate denture, with adequately defined borders."

DISADVANTAGES.

LIP FULNESS.

The problem of fulness of the upper lip is discounted by Van der Ven²⁹³ as a result of the acrylic materials now available. The labial flange may be made very thin and stained to produce a most satisfactory aesthetic effect.

Neill¹⁹¹ suggests that a wax sheet of the approximate thickness of the labial flange should be tried in position in the patient to assess the degree of fulness which may result with the denture. Necessary adjustments may then be made in the proposed treatment plan if the fulness should prove too great.

CLEAR LABIAL FLANGE.

Axelband¹³ suggests that the inclusion of a clear labial flange in the denture eliminates the construction of a separate clear base for surgical procedures.

With subsequent denture relining, the clear labial flange may be replaced by the same material as the denture base.