THE MYLOHYOID RIDGE AND ENDOALVEOLAR CREST: AN ANATOMICAL AND CLINICAL STUDY WITH REFERENCE TO PREPROSTHETIC SURGERY

B. PENHALL, L.D.S.,R.C.S.(England), F.D.S., R.C.S. (Edinburgh)

Department of Dentistry
The University of Adelaide

1992

CONTENTS

Page No.

SIGNED STATEMENT

This research report is submitted as part of the requirements for the Degree of Master of Dental Surgery in the Department of Dentistry, The University of Adelaide.

I declare that it contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except when due reference is made in the text.

NAME: .Brian Penhall COURSE: Master of Dental Surgery

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

SIGNED: DATE: 17.3.92.

ACKNOWLEDGEMENTS

Emeritus Professor Tasman Brown has advised and supported me from the outset, for which I am deeply grateful. Associate Professor Grant Townsend has patiently encouraged me with energy, enthusiasm and gentle insistence on achieving deadlines. He has made this work challenging and enjoyable. Without their support, little would have been achieved.

Dr David Roder of the South Australian Health Commission stimulated my initial interest in clinical research many years ago and I thank him for his continued support and interest. Professor Barrie Vernon-Roberts kindly permitted me to work with material in the Department of Pathology, Royal Adelaide Hospital and Mr Eric De Nardi made considerable efforts to provide me with appropriate specimens at awkward times.

I am appreciative of the invaluable assistance offered to me by Mr Graeme Pretty, Senior Curator, Archaeology, Dr Catherine Kemper, Curator of Mammals and her assistant Ms Lynette Queale of the S.A. Museum, and to Jim Johnson, Department of Anatomy, The University of Adelaide, who have all generously afforded me access to the collections and specimens in their care.

Mrs Shirley Hastings has devoted endless hours deciphering and typing my manuscripts and I especially appreciate her kindness and patience. I am indebted to Ms Angela Keane, Mrs Sandra Pinkerton and Mrs Wendy Schwerdt who have cheerfully undertaken countless tedious but essential chores associated with this work.

Thanks also go to my colleagues in the Anthropology Group of the Department of Dentistry, both fellow students and academic staff, for their continued comradeship and support.

Finally, any accolades due should go to my wife Sue.

PREFACE

This research report is presented in five main sections.

The first section provides a general review of the growth and development of the mandible and the soft tissues of the oral cavity leading on to a discussion of the edentulous state, including the changes that occur in the alveolar bone following tooth loss. Some of the newer approaches aimed at stimulating new bone growth are also mentioned. The more insidious changes that occur in the mouth following loss of teeth are described, including the changing behaviour of the tongue and the alteration of chewing patterns. The aims of this section are to highlight the need to appreciate the relationships between form and function, including the changing relationships of the various oral structures resulting from alterations to their form.

The second section provides a detailed review of the various surgical methods used to reduce discomfort from a prosthesis in the edentulous mandible. These include relative and absolute augmentation, lingual and labial sulcoplasty, the associated grafting of various tissues including the use of hydroxyapatite, and surgery of the mylohyoid ridge. The author's preferred method of mylohyoid ridge surgery is described and its advantages discussed. This section summarises the various approaches available to enable the construction of a comfortable denture in the badly damaged edentulous mandible. It indicates the advantages and disadvantages of these procedures and compares them with the relatively simple procedure preferred by the author which formed the basis of the clinical research included in this research report.

The third section of the report comprises an analysis of the results after treatment of 521 patients who were referred to the author for the construction of new dentures. All of these patients were edentulous and suffered pain and discomfort. They were divided into 3 groups according to the treatment they received. The outcomes of treatments were compared, including the influence of age and gender. The results showed that those patients who had undergone surgery to modify the mylohyoid ridge prior to construction of prostheses showed a more satisfactory treatment response than either those who were considered not to need surgery, or those on whom surgery was considered necessary but not carried out.

The fourth section of the report deals with the anatomy of the inner aspect of the mandible in the mylohyoid region. During surgical procedures the author became aware that not all of the bony exostoses in this region constituted the mylohyoid ridge. Another closely associated, but quite distinct crest of bone was discovered. Due to the paucity of literature reports regarding this area, a series of investigations involving collections of human and animal skulls, and the dissection of preserved cadavers and post-mortem specimens were carried out. These investigations revealed that a crest of bone, termed the endoalveolar crest, was present just above the mylohyoid ridge. It is described and its diversity of expression in humans and primates illustrated.

The fifth section provides a summary of the main findings of the study, including conclusions.

SECTION ONE

A REVIEW OF MANDIBULAR DEVELOPMENT AND ANATOMY, INCLUDING THE CONSEQUENCES OF TOOTH LOSS

INTRODUCTION

Anatomical texts often describe the various components of the body under group headings, i.e. systematically. For example, the majority of the nerves found in the jaws would be listed and described under the heading, the cranial nerves. Muscles would fit into particular groups such as the elevator muscles of the jaws, or the pharyngeal muscles, and so on. The tissues of a particular area may also be described and inter-related to give the reader an overall picture of a particular region, i.e. topographical description, but seldom is the range of variation present within and between individuals emphasised.

In this section the development and growth of the lower jaw is briefly outlined by referring to the texts of Sicher and Du Brul (1990), Last (1990) and Sperber (1989).

The changing morphology of the adult jaws following removal of the teeth has been well documented and is referred to (Tallgren, 1970, 1972; Atwood, 1957, 1962, 1971; van der Kuij, 1978, 1985 and Vingerling, 1985). The altered morphology and changing behaviour of the related soft tissue structures in the retromylohyoid region after tooth loss have not, however, received much attention in the literature.

As the alveolar bone height diminishes with resorption the mylohyoid ridge becomes sharper and appears to elongate posteriorly. These changes are recorded and, where appropriate, literature references are made. Less well known is the rearrangement of structures which may occur as a result of the altered behaviour of the tongue and submandibular glands, particularly where a prosthesis is not utilised. The description of these changes is the result of the author's experience as a clinician. They are documented in Section 1 (p.32) as they are thought to be the source of some confusion in the minds of prosthodontists and because, as a result of the discomfort frequently experienced by patients in this predicament, unnecessary and complex surgery is often carried out which further complicates the patients' problems. Surgical procedures are reviewed in Section 2.

Later, the author draws attention to the changes following loss of posterior teeth. The obvious change is loss of alveolar bone. Less obvious is the alteration in relative position of some muscle attachments, the sharpening and apparent elongation of the mylohyoid ridge, the alteration of the shape and size of the submandibular gland and the altered behaviour of the tongue.

EARLY DEVELOPMENT OF THE MANDIBLE AND ASSOCIATED STRUCTURES

Embryology

Branchial arches

The branchial arches are six tubular enlargements which form below the forebrain of the developing embryo in the fourth week *in utero*. Their formation is induced by the encounter of the neural crest cells which are migrating ventrally and caudally with pharyngeal endoderm.

Within each of the arches arise muscular, skeletal, vascular, connective tissue, epithelial and neural elements, that make up the systems of the head and neck (Fig. 1a). The first two arches are named the mandibular and hyoid arches respectively. The first (mandibular) arch develops for the most part into the mandible and maxillae. Both sides of this arch fuse ventrally in the midline and chondrification in the mesoderm produces Meckel's cartilage. The maxillary processes appear as a bulge on either side of the arch and grow towards the midline, meeting with each other and the medial and lateral nasal processes. With the fusion of the two palatal processes with the developing septum, the palate is formed to separate the oral cavity from the two nasal cavities. The incus and malleus are produced from the dorsal end of Meckel's cartilage which also gives rise to the ligament of the malleus and the sphenomandibular ligament. The lingula of the mandibular foramen is a small persistent part of the cartilage, as are the ossa mentalia (chin bones) which sometimes persist at the symphysis menti.

Meckel's cartilage (the cartilage of the first arch) provides the template around which the mandible develops. By five weeks condensation begins lateral to Meckel's cartilage in the region of the future mental foramen (Fig. 1b). The mandible forms separately on each side as a membrane bone and by the seventh week much of the body and the ramus are recognisable,

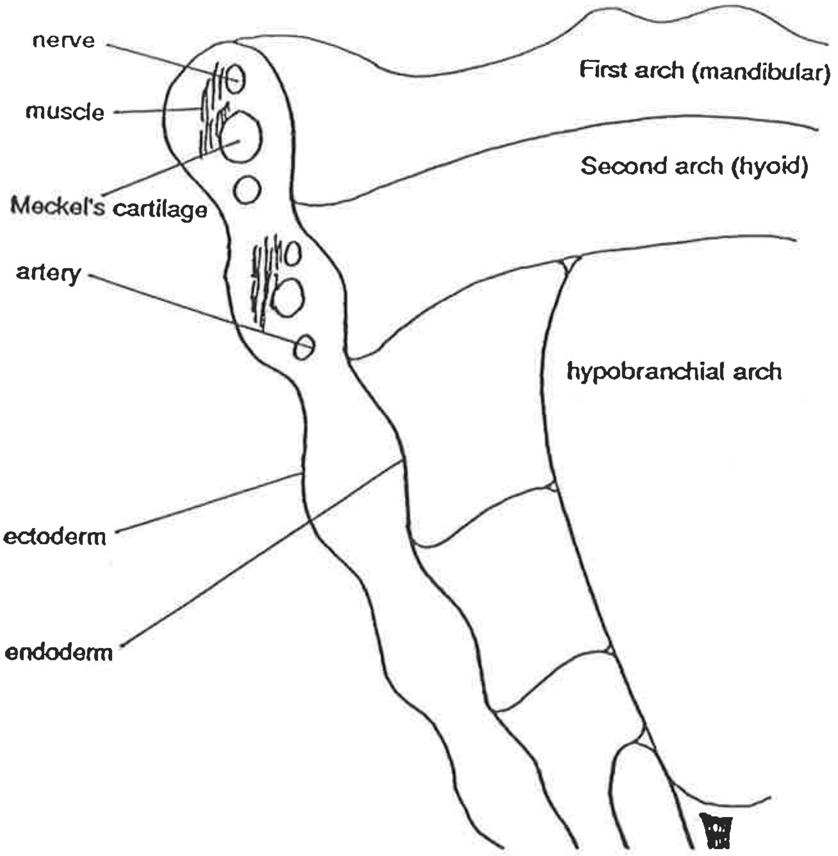


Fig. 1a. One side of a section through the primitive stomadeum. The hypobranchial eminence is formed by proliferation of the mesenchyme in the second, third and fourth arch and is involved in the formation of the tongue.

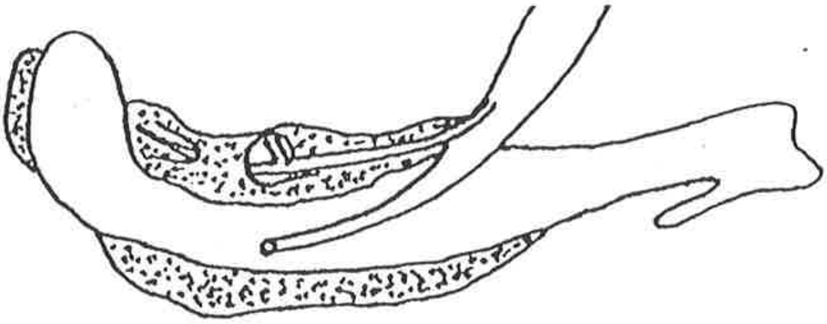


Fig. 1b. Condensation of bone (shaded area) around Meckel's cartilage. The mandible develops as a condensation of mesenchyme lateral to Meckel's cartilage which largely disappears.

though still separate. By eight weeks condensation of bone and secondary cartilage in the condylar growth centre is readily seen. The condylar cartilage is rapidly transformed into bone except at its proximal end and the mandible, together with condylar cartilage, is recognisable by four months. The proximal end of the condylar cartilage is enveloped in a fibrous covering continuous with the joint capsule, and the cartilaginous head continues to function in a way similar to the epiphyses of long bones until about the twenty fifth year.

At birth the two rami are quite short and the eminence on the temporal bone is poorly developed. Although the condyle contributes substantially to postnatal growth the remodelling of the surfaces of the remainder of the ramus and the body is of considerable importance when considering the final adult dimension.

The mesodermal derivatives of the arch include the muscles of mastication: masseter, temporalis, lateral and medial pterygoids. In addition the two tensor muscles, tensor palati and tensor tympani, together with the mylohyoid and the anterior belly of the digastric muscles are generated from this source. All derive their motor innervation from the nerve of the first arch, the mandibular division of the 5th cranial nerve, the trigeminal.

Muscles of the mandible

The earliest of these muscles to differentiate are the mylohyoids, and the anterior belly of the digastric, which probably accounts for the early mouth-opening ability of the fetus. The mylohyoid muscles cradle the tongue by meeting in the midline at a raphé.

The muscle masses interact with cells from the neural crest which are forming into the cranial nerves. The mylohyoid thus carries its nerve supply with it, a small motor branch from the inferior alveolar branch of the mandibular nerve. The sensory innervation of its covering mucous membrane is served by the lingual branch itself.

The mylohyoid muscle is initially attached to the ventral border of Meckel's cartilage but later migrates dorsally to attach to the body of the foetal mandible. At birth the mylohyoid and buccinator muscles are closely related on the dorsal surface of the body of the mandible. They later move downwards relatively as the alveolar bone grows upwards to support the erupting teeth. The mylohyoid then comes to lie with its posterior border, mesial to and below the last molar tooth, whilst the buccinator occupies a similar location on the lateral side.

The tongue

The complexity of the tongue's development is illustrated by its diverse innervation. The mucosal covering of the anterior two-thirds is derived from the first branchial arch and is supplied by sensory branches of the lingual nerve. The taste buds, derived from both ectodermal and endodermal cells, are special sensory organs with their cell bodies in the geniculate ganglion of the seventh (facial) cranial nerve and innervated by the chorda tympani nerve which joins the lingual nerve. This branch also carries parasympathetic secreto-motor fibres to the sublingual gland from the superior salivatory nucleus. The chorda tympani nerve is considered to be the pretrematic branch of the second branchial arch nerve (facial) which invades first arch territory.

The motor innervation of the tongue by the 12th cranial nerve (hypoglossal) reflects its occipital somite origin. The muscle mass pushes forward in the floor of the pharynx as the hypoglossal cord, carrying the hypoglossal nerve with it.

The posterior third of the tongue is separated from the anterior portion by the sulcus terminalis in front of which lie the vallate papillae, innervated by the glossopharyngeal nerve. This nerve carries fibres of common sensibility and taste (afferent) and in addition supplies parasympathetic secreto-motor fibres (efferent) to the glands within the buds.

Although the whole of the stomodeal chamber is filled by the rapidly enlarging tongue, it is also enlarging as the mandible moves downwards and spreads laterally. The tongue thus descends to allow the developing palatal shelves on each side to meet and fuse.

At birth the tongue entirely fills the oral cavity and it continues to grow rapidly to maintain the infant tongue posture of suckling.

Post-natal growth of mandible and soft tissues

For many years the condyle was considered to be the primary growth centre of the mandible and it was thought that the condylar cartilage provided the principle force causing the assumed downward and forward displacement of the mandible (Figs. 2a and 2b). The growth of the condyle and its influence on the development of the mature mandible has provoked much conjecture and stimulated transplantation experiments devised to demonstrate its independence. Being a secondary cartilage, the condylar cartilage is presumed not to exhibit the degree of intrinsic growth potential of a primary cartilage.

Rushton (1944) suggested that damage at an early age to this area may be followed by reduction in growth. However, only minor changes following careful condylectomy in animals (Sarnat, 1963), or no changes (Gianelly and Moorees, 1965), have in fact been observed. It is now suggested that observed disturbances following early damage may be due to contraction and fixation by scar tissue rather than loss of growth potential. Koski and Rönning (1965) have shown that transplanted condylar cartilage, unlike epiphyseal cartilage, has little independent growth potential when transplanted alone, however, when transplanted with its adjacent bones, it does. It is well documented that some mandibles position themselves normally and appear to function adequately when the condyles are absent. Moss and Rankow (1968) confirmed that careful surgical resection of the head of the condyle in childhood interferes little with mandibular growth.

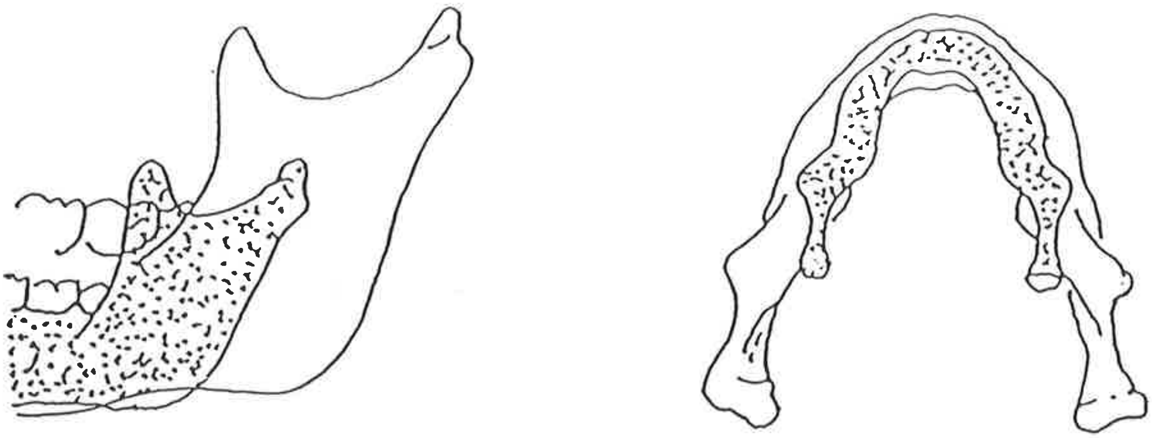


Fig. 2a. Diagrammatic representation of mandible from child to adult to show changes in size and dimension.

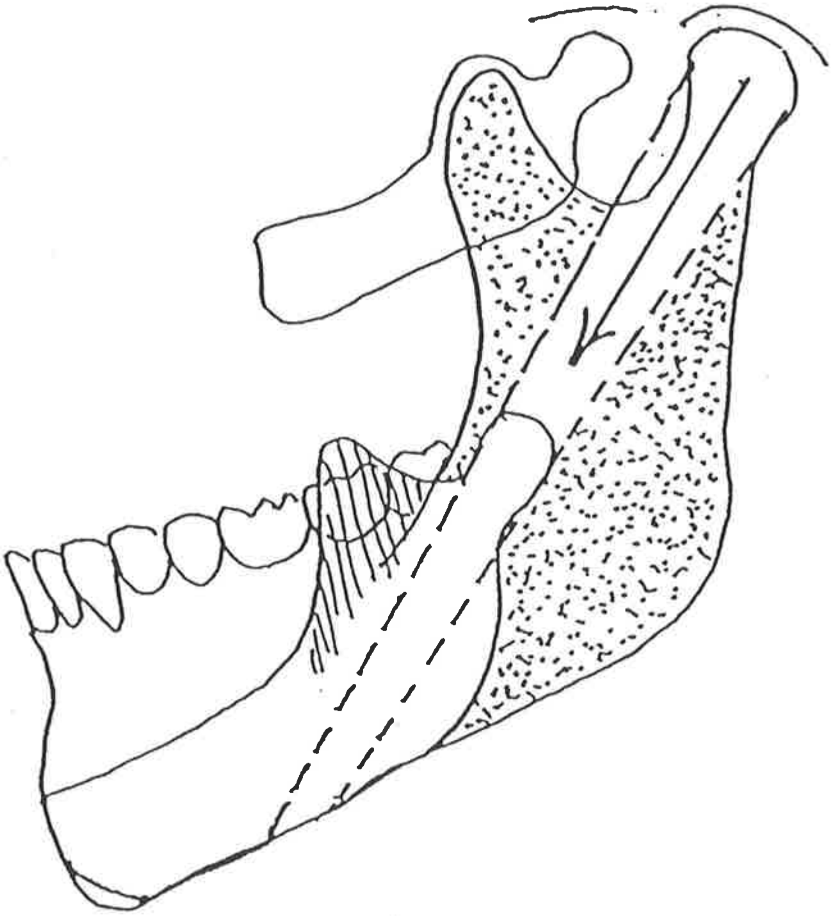


Fig. 2b. Diagrammatic representation of growth from early embryo to adulthood (after Weinmann and Sicher). Note the dominance which was attributed to condylar growth.

Moss and Salentjin (1969) tentatively argued that the skeletal tissues grow only in response to soft tissue growth. In the "functional matrix" theory, Moss identifies two large enveloping capsular matrices, the cerebral and the facial matrices. He divides the skull into a series of discreet functional components, each comprised of a functional matrix, either periosteal or capsular, together with an associated skeletal unit. A periosteal functional matrix controls remodelling and the size and shape of a bone, as it affects deposition and resorption of bony tissue (e.g. the interaction of the temporal muscle and the coronoid process of the mandible). According to Moss, each component of a functional matrix performs a necessary service, e.g. mastication, speech, respiration. Whilst the skeletal tissues support and protect the associated functional matrix, Moss suggested that the two large capsular matrices, cerebral and facial, contain specific tissues, structures and physiological spaces. The spaces must remain open to fulfil their functions. As each capsular matrix expands, together with its associated elements, all of the bones, endochondral and intramembranous, grow to maintain the physiological spaces. This argument supports the observation that altered physiological patterns can affect skeletal growth and suggests again that perhaps the condyle does not play the role of master growth centre or cause mandibular displacement.

Johnston (1990) writing in a monograph published by the University of Michigan, entitled his contribution, "The functional matrix hypothesis: reflections in a jaundiced eye." He and his colleagues detached guinea-pig condyles from the body of the mandible. Under these experimental conditions the condyles continued their upward growth whilst the ramus collapsed upwards because of the pull of the muscles attached to it. Later the two parts were reunited and normal growth continued.

In addition to attempts to explain "how " the various components grow, much study and experimentation has been directed to the factors which "control" skeletal morphogenesis. Van Limborgh (1970) divided these factors into five groups: intrinsic genetic factors, local and general epigenetic factors, and local and general environmental influences.

As the knowledge of genetics has increased over the years it has become apparent that predictability of the craniofacial form of children by examination of their parents, cannot be undertaken by applying simple Mendelian principles. For example, although it is possible to predict precisely the ABO blood type of progeny, the complexity of genetic influences on the craniofacial skeleton, in addition to superimposed environmental influences, complicates the exercise of prediction.

Function has a profound effect on the outcome of growth and the results of various malfunctions, e.g. abnormal tongue behaviour patterns are well documented and offered as examples of one cause of malocclusion. General body growth can be influenced by exercise-promoting growth spurts or malnutrition, which can inhibit development and these are undoubtedly factors which can also modify craniofacial growth.

Various other influences, such as the effects of orthodontics and orthognathic surgery, which are practised in an attempt to modify deviations from normality and which now play a quite acceptable part in modern daily life, are beset with problems. Relapse following orthodontic treatment or surgery on the growing child, or the effects of either treatment on subsequent growth, is often difficult to predict.

Bone growth continues until maturity by a complex mixture of two basic processes, deposition and resorption. These are carried out by growth fields comprised of the soft tissues investing the bone (Moss, 1962, 1969). Because the fields grow and function differently on different parts of the bone, the bone undergoes remodelling, i.e. shape change. When the amount of deposition is greater than the resorption, enlargement of the bone necessitates its displacement, i.e. its physical relocation, in concert with other bone displacement (Fig. 3a). Enlow and Hunter (1968) suggested surface deposition coupled with selective resorption could explain growth of the ramus. This observation had been apparently postulated by Humphrey (1863) following his growth experiments on pigs. Wire rings which were inserted into the anterior and posterior borders of the ramus in the young pig were later relocated, in that the anterior rings were discovered in soft tissues whereas the posterior rings were more deeply embedded.

Enlow (1968) introduced his "V" principle concept, when describing remodelling, as a process of reshaping and resizing resulting from progressive continuous relocation (Figs. 3b and 3c). This idea was used to clarify the complicated remodelling during growth of the mandible. It was suggested that not only does each condylar head, during its growth, fit into the "V" principle but that the two condyles also represent the terminals of a "V" which is moving and diverging. The width increases to keep pace with the cranial base. Whilst condylar width increases and the enlarging body widens resulting in increased height and length of the body, the width in the canine region increases little after about six years.

The condyle is attached to the temporal bone by the capsular and temporomandibular ligaments and the mandible is cradled in space by the medial pterygoid and masseter muscles. As the upper cervical vertebrae lengthen they carry the cranium and upper face away from the mandible and the potential space is filled with new cartilage.

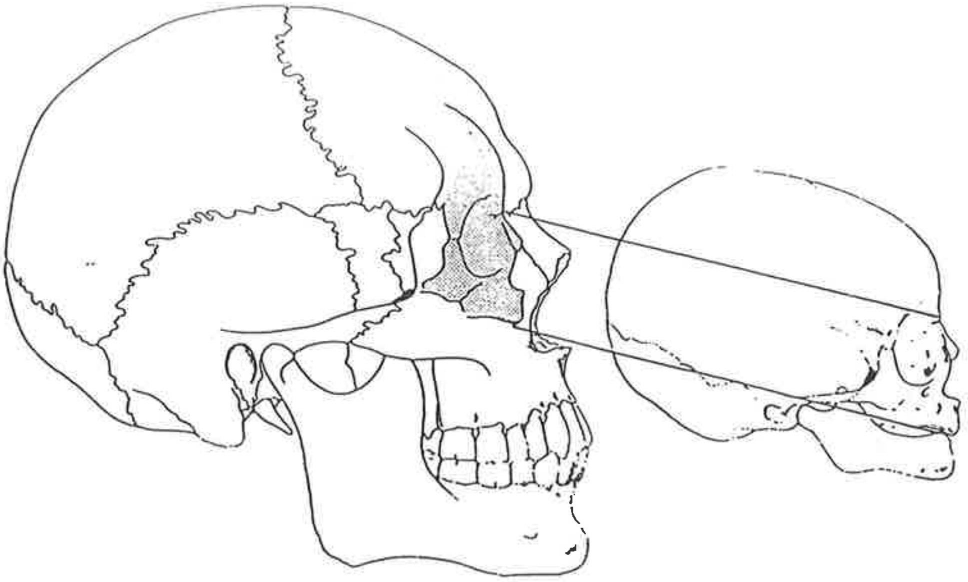


Fig. 3a. Remodelling is accompanied by relocation. The nasal area of the adult occupies a position where the maxillary arch had been located in early childhood.(Enlow,1990)

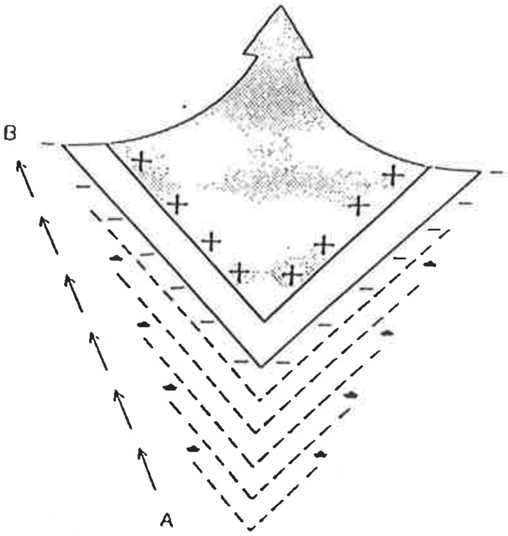


Fig. 3b. Enlow's "V" principle. He suggests that as many cranial and facial bones have a V shaped configuration and as deposition occurs on the inner side of the V and resorption on the outer surface, the V thereby moves from position A to B. At the same time it increases in dimension. (Enlow 1990)

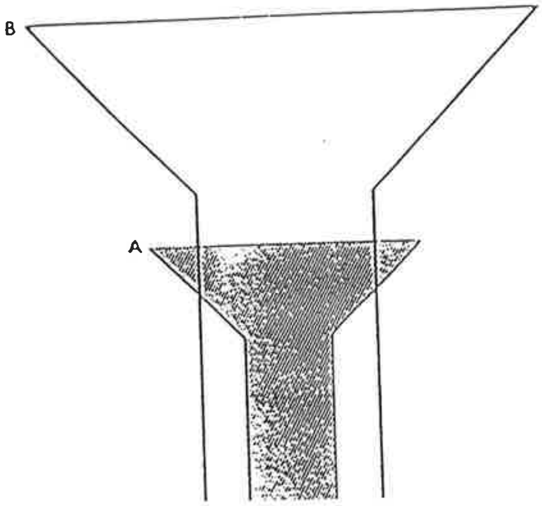


Fig. 3c. Remodelling converts a wider part into a narrower part as relocation takes place, i.e. the diameter at A is reduced as the broad part of the bone is relocated to B.(Enlow 1990)

MORPHOLOGY OF THE MANDIBLE

Bony landmarks (Fig. 4a)

There are remarkable inconsistencies from text to text regarding the precise location of ridges, spines, tubercles and roughened areas which serve as the origins and insertions of the various muscles of the body.

At maturity the mandible consists of a horseshoe-shaped body that continues on either side upwards and backwards into a mandibular ramus. In the sagittal plane the ramus is flattened and ends in two processes bounded by a concave border. The anterior coronoid (or muscular) process provides insertion for much of the temporalis muscle and the posterior condylar (or articular) process is the means by which the mandible articulates with the base of the skull. The posterior border of the ramus and the inferior border of the body meet at the mandibular angle.

The alveolar process is joined to the upper border of the body but whereas the body in its posterior part flairs outwards in an oblique plane directed posteriorly and laterally, the alveolar process remains more vertical in its orientation and turns much more to a sagittal plane as it continues posteriorly. The distal part of the alveolar process is narrower therefore than the arch of the mandibular body. The molar teeth thus occupy a position within the mandibular arch with the mandible viewed from above. Although the position of the mental foramen in the adult can vary, it is usually found halfway between the crest of the alveolar bone and lower border of the mandible and near the root apices of the premolar teeth. The changing shape of the residual bone following the loss of teeth results in a rearrangement of these structures such that their relationship, one to the other, is altered. This is discussed later.

The insertions of the temporalis and superior constrictor muscles, the pathway of the lingual nerve and its relationship to the mandibular body, and the origin of the mylohyoid muscle deserve closer attention because their

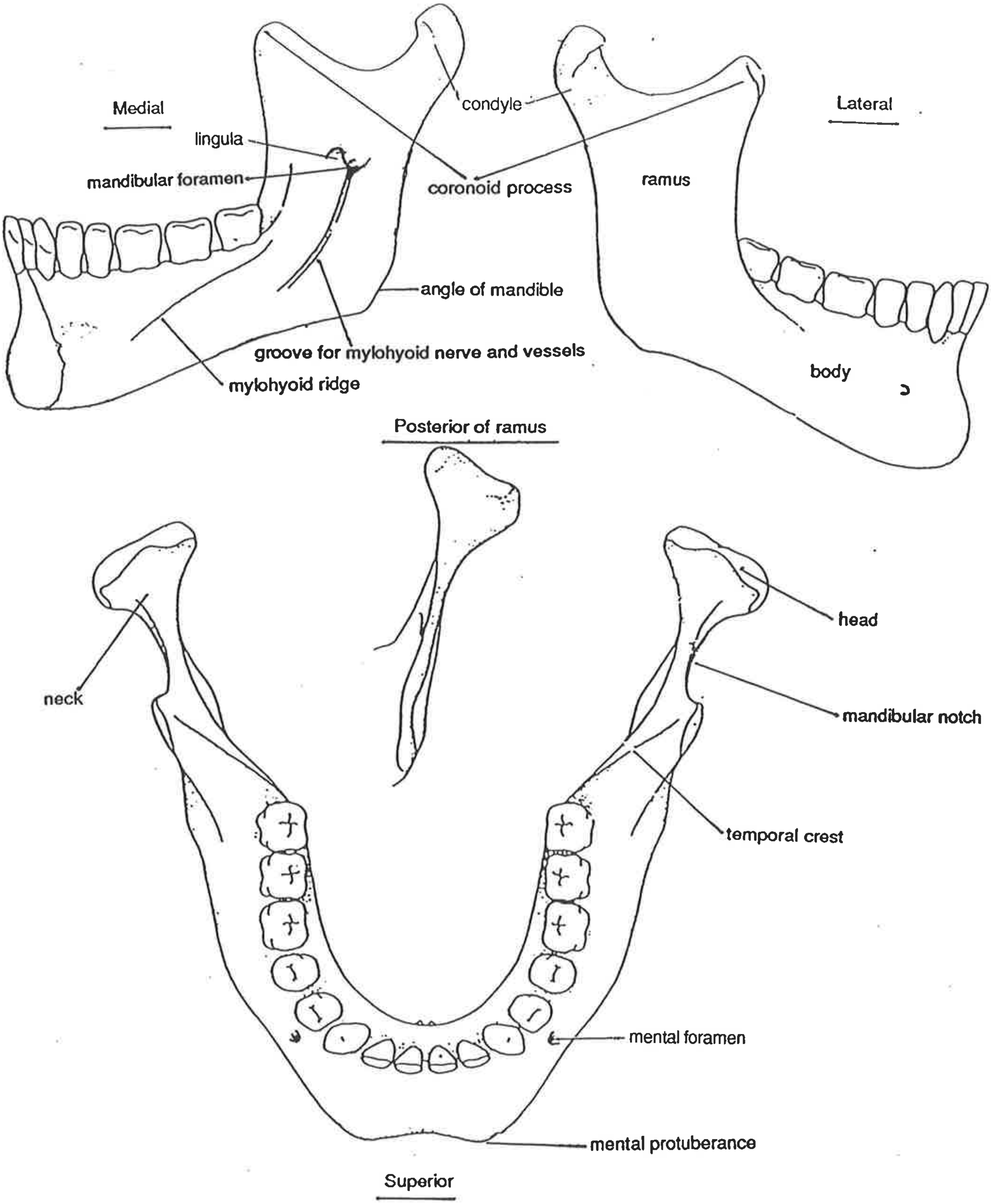


Fig. 4a. Bony landmarks of the mandible

relationships have significance in the surgical techniques applied to this anatomical region. On the inner surface of the mature mandible the mylohyoid ridge commences 5-6 millimetres below and a little behind the last molar tooth. It provides attachment for the mylohyoid muscle as it passes obliquely forwards and downwards towards the midline (Fig. 4b).

The mylohyoid ridge, with the lingual nerve adjacent to it, is not distinctly obvious in the normal mature mouth. The mucous membrane, as it sweeps up to cover the pharyngeal muscles, serves to dull the detail of these structures. Medially the mucosa originates from its attachment to the necks of the teeth and sweeps downwards to cover the mylohyoid ridge and the deep portion of the submandibular gland, finally reflecting upwards to envelop the tongue. The resulting pouch of mucous membrane (the retromylohyoid fossa or posterior lingual sulcus) constantly changes shape due to the influence of the changes in the structures immediately below its surface covering.

During swallowing, for example, the medial pterygoid contracts to support the mandible. The mylohyoid contracts to raise the floor of the mouth and the structures closely connected to the floor, including the submandibular gland, move upwards in concert. At the same time the tongue muscles move the tongue laterally and as a consequence the sulcus dramatically alters shape.

The mylohyoid ridge, behind the last molar tooth, is often traceable upwards towards the lingula and on to the head of the mandible, thus forming an additional mechanical strut to the mandible. In front of this the anterior border of the ramus is bevelled from the tip of the coronoid process down to the retromolar fossa and the upper border of the body. The lingual nerve emerges from beneath the mylopharyngeus and passes above the mylohyoid ridge, between it and the last molar tooth, covered only by mucous membrane, before passing mesially into the tongue. The bone

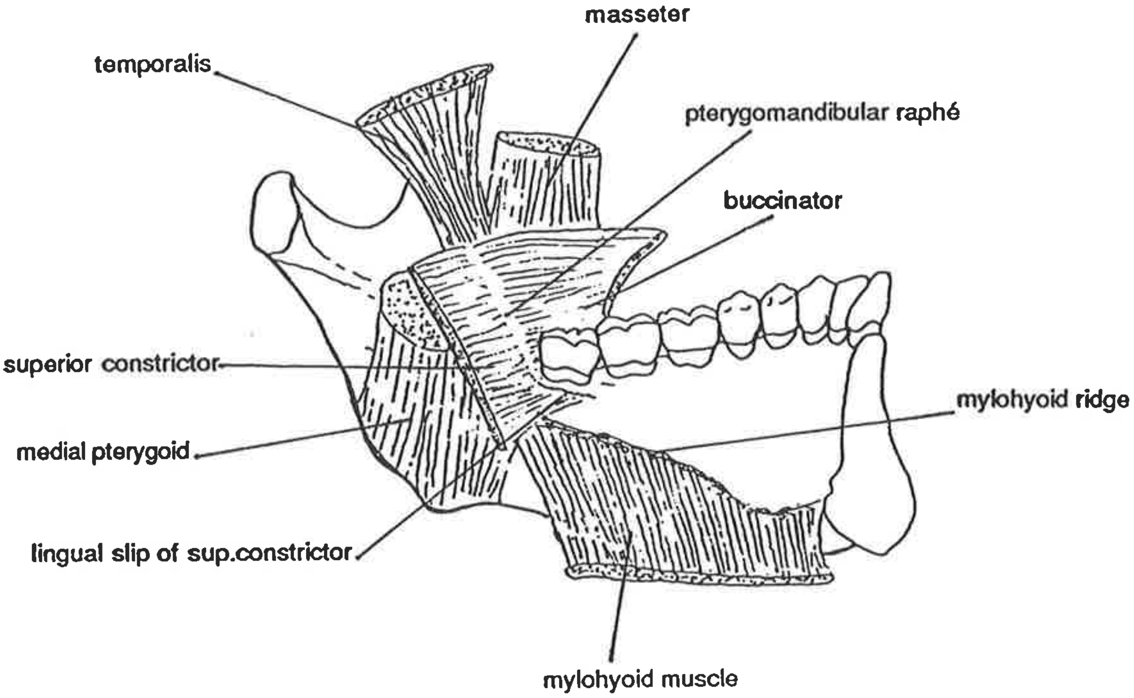


Fig. 4b. Diagram to show the muscles associated with the posterior lingual aspect of the mandible.

above the lingual nerve groove gives attachment to the superior constrictor muscle at the lower attachment of the pterygomandibular raphé. This bony attachment is frequently characterised by a marked ledge of bone which merges with the lingual alveolar crest of the last molar tooth. It has been described as the "endoalveolar crest" (Waite, 1978) and is separate from the alveolar bone, remaining as a distinct entity following the remodelling after extraction of the 3rd molar.

Relevant muscles

Superior constrictor muscle (Fig. 4b)

This muscle is described by Du Brul (1990) as having four quite distinct subdivisions which are separate according to their origins.

The uppermost fibres arise from the lower third, or fourth, of the medial pterygoid plate at its posterior border; from the small ligament that bridges the hamular notch, and from the tip of the hamulus itself. The next section of the superior constrictor takes its origin from the pterygomandibular raphé, the tendonous band stretching from the tip of the pterygoid hamulus to the retromolar triangle of the mandible. Since, anteriorly, fibres of the buccinator muscle arise anteriorly from the raphé, the second part of the superior constrictor is called the buccopharyngeus muscle.

The third part of the superior constrictor is the mylopharyngeus muscle (often referred to as the lingual slip of the superior constrictor). According to Du Brul, the muscle fibres themselves do not originate from the bone but "arise from the membranous floor of the oral cavity and are, by the intervention of this membrane, indirectly attached to the mandible". This muscle bundle is often referred to as the lingual slip of the superior constrictor muscle.

The fourth (lowest) part of the superior constrictor consists of a variable number of muscle bundles that are the continuation of some longitudinal and transverse fibres of the tongue. This part of the superior constrictor is therefore designated the glossopharyngeus muscle.

It is important to understand that although the pterygomandibular raphé is described as a tendon, it is only its appearance when the mouth is open that gives rise to that description.

Mylohyoid muscle

Commonly called the floor of the mouth, this muscle was originally called the oral diaphragm. The right and left muscles unite in a midline raphé between the mandible and the hyoid bone. About one quarter of the posterior fibres converge to be inserted into the body of the hyoid. Each muscle arises from the mylohyoid line on the inner surface of the mandible. The most posterior fibres arise about 5 mm below the third molar tooth, immediately below the lingual nerve as it enters the mouth from beneath the lingual slip of superior constrictor. The posterior fibres are thicker and more coarsely bundled, running steeply downward and forward to the hyoid bone. The origin of the more anterior fibres deviate more to the anterior lower border of the mandible, to interdigitate with fibres from the opposite side in the mylohyoid raphé.

Du Brul states "because of the origin high up on the inner surface of the mandible, the muscle plate of the mylohyoid and the inner surface of the mandible bound a niche, the mylohyoid or submandibular niche. It is deepest posteriorly and more shallow anteriorly". Although this muscle is often described as a depressor of the mandible and exhibits constant electrical activity from its contracting fibres during mastication, Du Brul suggests that only the most posterior (almost vertical) fibres can actually play a part in this manoeuvre. While the mandible is fixed (i.e. teeth together), contraction of these fibres will tend to raise the hyoid bone. Similarly, with the hyoid bone fixed, contraction of the fibres may contribute to depression of the lower jaw. The anterior fibres serve to elevate the tongue and help with its protrusion as they contract to raise the floor of the mouth during deglutition. Last (1990) suggests that its action is to form a mobile, but stable, floor to the mouth and support the weight of the tongue.

The mylohyoid muscle, superior constrictor muscle and pterygo-mandibular raphé change their relationship to the body of the mandible after the loss of posterior teeth. As the alveolar bone resorbs and moves downward towards the mylohyoid line, the mylohyoid muscle appears to migrate towards the crest of the remaining bony ridge until it bears a very close relationship in its new position to that previously occupied in the newborn infant, before growth of the alveolus and eruption of the teeth, i.e. on, or near the crest of the mandibular body.

Buccinator muscle

Most authors are in agreement regarding the most posterior attachments of buccinator. A classic description given by Last (1990) states that "the muscle arises from both jaws and the pterygo-mandibular raphé. The line of origin in the upper jaw commences in front of the first molar, well away from the alveolar margin passing horizontally backwards, skirting the root of the zygomatic process and curving downwards to the tuberosity of the maxilla. Here there is a gap in the bony origin, the muscle arising from a fibrous band (sometimes called the pterygomaxillary ligament, and not to be confused with the pterygomandibular raphé) that extends from the tip of the hamulus to the nearest part of the tuberosity of the maxilla. Through the gap above this band passes the tendon of tensor palati as it hooks around the hamulus. From the tip of the hamulus the pterygo-mandibular raphé extends to the mandible just above the posterior end of the mylohyoid line. Buccinator arises from the whole length of the raphé, along which it interdigitates with the fibres of superior constrictor. The mandibular attachment of the raphé is separated by a narrow interval from the posterior attachment of the mylohyoid muscle to the mylohyoid ridge; here the lingual nerve rests on the mandible which it often grooves."

The buccinator fibres pass downwards outwards and forwards from the pterygomandibular raphé and passing behind the last molar tooth gain attachment along the external oblique ridge of the mandibular body. "As they do so they complete the formation of a very definite pouch in the cheek which lies on the lateral surface of the mandible and is 1.5 cm in depth, almost covering the mental foramen (Barker, 1979)."

At birth and senility "sans" teeth this muscle tends to lie much closer to the surface of the mandibular body. In the edentulous state there is an apparent migration of the attachment as resorption progresses, until it comes to lie on the outer border of the body, level with the surface of the remaining bone, thus effectively reducing the buccal pouch (Barker 1969, 1979).

CHANGES IN ALVEOLAR BONE FOLLOWING TOOTH LOSS

Continual reduction of the residual alveolar ridges

Of the many writers who have sought to clarify the rather complex phenomenon of progressive residual ridge resorption (RRR) associated with tooth loss, Tallgren (1957, 1967, 1969, 1970) and Atwood (1957, 1962, 1971) have made outstanding contributions in regard to their observations in humans (Figs.5). Pietrokovski and Massler (1971), together with Mitzutani and Ishihata (1976), studied the patterns of bone loss following tooth removal in rhesus monkeys. The results of these studies correlate well with Tallgren's observations in humans in the early years following the removal of the teeth. More recently Jaul, McNamara and Carlson (1980) reported on a study involving four female rhesus monkeys which had complete dental clearances and which were monitored over a period of nearly four and a half years (234 weeks). The results were derived by assessing the changing relationships of the remaining bone to 29 tantalum implants inserted into

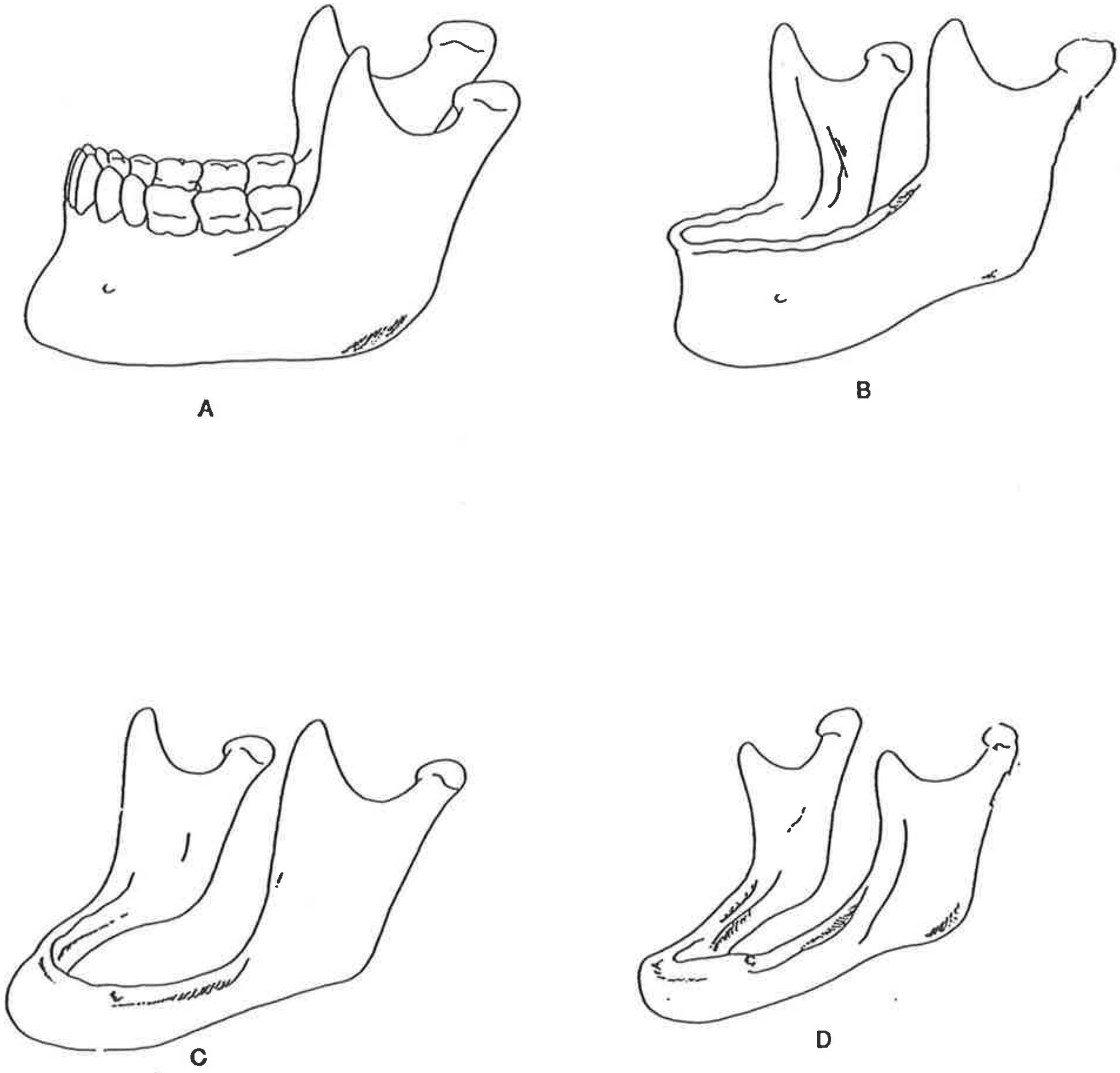


Fig. 5. The changing shape of the mandible after tooth loss. The loss of alveolar bone height is obvious but note that in d there is narrowing of the ramus and an increase in the mandibular angle.

chosen bone sites using the methodology described by Björk (1963), and into soft tissues, as described by McNamara (1972) and McNamara and Graber (1975).

What is of particular interest in the study by Jaul and his colleagues is that they noted and measured the changes in the whole maxillae and mandible. Their judicious placement of implants, which included three in the frontal bone and five in the midline of the cranial base on each side of the spheno-occipital synchondrosis, made for relatively simple superimposition of successive cephalograms. Significant changes were evident in the ramus, the condyle and the gonial region, the remodelling of these areas continuing throughout the entire length of the experiments. In particular, the anterior border of the ramus showed marked resorption, 50 percent of the total resorption taking place in the first 48-week period. Although deposition occurred along the posterior border of the ramus, the amount was less than that resorbed from the anterior border. The distribution was also such that the ramus, after 234 weeks, was narrower and located more posteriorly.

There was also an overall upward and backward displacement of the condyle, in line with the direction taken by the posterior border of the ramus. This resulted from continual bone deposition along the posterior border of the condyle.

Despite the differences in species studied and other confounding factors, such as the wearing of dentures in the human studies, the patterns of bone loss in these studies were remarkably similar. Of particular interest, Tallgren suggests that careful assessment of mandibular shape prior to extraction may well provide a prediction of the likely response of the residual ridges to denture wearing.

Pattern of alveolar bone loss

The magnitude and pattern of alveolar bone loss shows great individual variation. In this regard, however, it should be noted that, apart from Jaul's healthy monkeys, there are no data to show the condition of the bone prior to tooth extraction. Atwood (1962) attempted to ascertain the reason for extraction of teeth but stated that in many instances subjects were unsure. It is reasonable to suggest that if the reason for tooth removal was periodontal disease (as opposed to rampant caries) then the ravages of the disease may continue to cause bone loss for some time after the removal of the cause.

Both Tallgren and Atwood suggest that the most rapid period of bone loss is in the first six months post-extraction. Thereafter the rate slows and on average the mandible continues to lose height at the rate of 0.4 mm per year. To emphasise the extent of individual variation, Atwood (1971) reports the extent of bone loss in one subject studied over a period of 19 years. During the first three years the anterior vertical RRR was 3.0 mm in the maxillae but further bone loss, if any, was immeasurable over the ensuing period; whilst the mandible, after a dramatic early bone loss - almost 11.00 mm in the first three years - continued to reduce at a steady rate of 0.4 mm to a total reduction of 14.5 mm in 19 years.

All authors highlight the continual pattern of resorption, especially of the lower ridge, and point out the serious consequences of relentless bone loss. Over a 20-year period, vertical loss of some 10 mm of bone may result in a dental cripple (Tallgren, 1966, 1972).

Atwood and Tallgren have illustrated the changes in residual ridge shape which may take place over the years, the cross-sectional shape of the residual ridge altering from being "high well rounded" to "low well rounded" after some years, and then to a "depressed" form commonly seen in patients after many years of denture wear (Fig. 5). In these cases there appears to be no ridge at all and some muscle attachments, like the mylohyoid ridge and the genial tubercles, are the sentinels which warn the prosthodontist of the impending difficulties he/she will encounter.

It is interesting to focus further on the results recorded by Jaul and colleagues in regard to the rhesus monkeys that they studied. The greatest amount of mandibular residual resorption occurred during the first 24 weeks post-extraction and this accounted for a reduction of 42% to 63% of the total vertical reduction in the mandible over the experimental period. Following this initial reduction, resorption continued at a slower rate in the anterior and posterior regions. The middle region of the mandible, as well as the maxillae, exhibited a much greater rate and amount of resorption particularly between the 48 and 168 week interval, i.e. in the mid-period of the experiment. "The greatest amount of residual ridge resorption in the mandible was found at the position mesial to the first molar, while the posterior and anterior regions of the mandibular residual ridge both evidenced a similar, though less pronounced, reduction." As Jaul states further, "Under normal circumstances, compressive stress resulting from jaw closure during mastication is transmitted through the teeth, to the periodontal ligament, and finally to the underlying bone. In the absence of the dentition, however, the compressive forces fall directly on the periosteal envelope of the residual bone, resulting in a relatively greater resorption of residual bone along those regions of the ridge which receive the greatest loads. Therefore, in terms of the data presented herein, the region mesial to the first molar is probably where the monkeys chewed their food most vigorously, leading to a relatively greater amount of compressive force on the periosteum of the residual ridge, an anatomical entity not structurally suited to withstand compressive forces, resulting in a relatively greater degree of bone resorption."

There were other interesting changes in bony morphology noticed by the Jaul team, notably the change in shape and ultimate size of the ramus. They noted what they described as a "normal amount of bone deposition along the posterior border of the ramus". They then describe the works of Dovitch and Herzberg (1968) and Trieger and Herzberg (1970) who studied the bony trabecular changes in the human mandible - from birth to the prenatal period and the similar changes in trabecular patterns in a macaca rhesus monkey experimentally rendered edentulous. They conclude that changes in muscle function and in biochemical stresses occur following complete extraction. They state, "There appears to be a decrease in the functional forces generated by the temporal and masseter muscles following extraction and a change in the trabeculation of the medullary cavity of the mandible in the ramus, condylar neck, and gonial region suggestive of reduced biochemical stresses". They go further by stating, "This is supported by recent histochemical studies of the temporal muscle in human patients with complete dentures".

Some controls of bone loss

The morphology of the mandible which has been edentulous for many years displays considerable individual variability. One factor influencing bone loss after loss of teeth seems to be gender. At, and just after the menopause, it is recorded that hormonal changes in females can give rise to a generalised osteoporosis, which is often subclinical. Indeed, the need to rebase a denture every 6-12 months would constitute sufficient reason to suspect osteoporosis in a postmenopausal female, in the absence of any other reasons for the obvious changes, particularly if this was occurring in the maxillary complex. In his practice, the author has noted the history of seventeen females where there was a suspicion of unusual circumstances necessitating frequent denture alterations. In twelve cases (about 70%) blood tests and forearm density tests pointed to osteoporotic changes. Furthermore, in all of these subjects blood tests demonstrated either a lack of one or another required hormones or, at least, a concentration of a hormone at the low level of the normal range. All of the subjects reported "odd" symptoms, which they were often embarrassed to relate for fear of sounding silly and, in addition, all subjects reported a noticeable improvement in general well-being and libido when hormonal balance was restored. This is not scientifically verified research but worthy of note within the context of this research report.

Mandibular bone density has been compared with total body calcium (TBC) and the bone mineral content of the radius to show that a significant relationship exists (Kribbs, Smith and Chesnut, 1983). A significant difference in forearm bone density in men requiring vestibuloplasty compared with age-matched controls with intact dentitions has also been reported (Rosenquist, Baylink and Berger, 1978). Nearly 20 years ago Phillips and Ashley (1973) researched the relationship between periodontal disease and metacarpal bone indices and showed that a weak relationship existed. Ward and Manson (1973) also published data on the same subjects.

Kribbs, Chesnut, Ott and Kilcoyne (1989, 1990), have continued these investigations and over the years have fine-tuned their methods. The first of their two articles reported on bone density in the mandible and other bones in an osteoporotic population of 85 postmenopausal women, while the second paper involved 50 normal women. All of this work was meticulously carried out and carefully controlled and the teams went to great lengths to eliminate compounding variables by using complex and sophisticated investigative and statistical methods. Kribbs (1990), writing independently, then reported on a comparison of mandibular bone in normal and osteoporotic women.

Kribbs and her colleagues recorded a number of observations:

1. Significant correlations were noted between mandibular bone mass and total bone mass.
2. The cortical thickness at the gonion was reduced in postmenopausal women, and this correlated strongly with several other bone mass measurements suggesting that it is related to generalised skeletal bone loss.
3. There was a strong correlation between TBC and mandibular bone mass suggesting that in an osteoporotic population, mandibular mass better reflects the status of the entire skeleton than the status of the wrist or vertebrae.

Kribbs (1990) goes to some length however to emphasise that although there are significant differences between normal and osteoporotic populations in mandibular bone mass and density, in cortical thickness at the gonion, and also in tooth loss in the mandible, there is considerable overlap between osteoporotic and normal groups. She reiterates, that only radiographic evidence of vertebral crush fracture enables a positive diagnosis of osteoporosis. As is stated in the 1989 paper, "Bone loss without fractures has no clinical significance until fractures have occurred, with the exception of resorption of the edentulous alveolar ridge".

The most severe cases of resorption are frightening in their presentation. It is not uncommon to discover that the mandible consists of a thin ribbon-like structure composed of a lowered external oblique ridge connected to its contralateral ridge by a sliver of bone, the innermost boundaries being the lowered mylohyoid ridges. By this time the lowered mylohyoid ridges appear to have fused with the internal oblique ridge of the ramus and continue forwards to meet and fuse with the genial tubercles. They frequently mimic the simian shelf of primates and frequently the genial tubercles and the genioglossus muscle often lie as much as 8-10 mm above the lowered lingual sulcus.

Stimulated bone growth

Bassett, Pawluck and Pilla (1974) demonstrated improved healing of bone fractures by surrounding them with pulsating electromagnetic fields. Following their early success they treated patients with two different types of pulsating electromagnetic fields: either a single pulse signal with a frequency of 70 Hz or a pulse train signal with a frequency of 15 Hz.

Vingerling et al. (1985) working with hamsters said: "Normal resorption means that in the process of resorption and apposition of bone, there is more resorption than apposition. So, by reducing resorption either the apposition process was stimulated or the resorption process was slowed down". These authors thus set about designing experiments to demonstrate a distinction between the two processes.

First and second molars from young hamsters were used to study growth, the logic being that, though teeth differ from bone, there is no resorptive process demonstrable in tooth germs of permanent teeth. To study resorption the experimental material used was hamster calvaria.

The results showed that M1 (first molars), which start to calcify at the time of birth, were not affected by the pulsing electromagnetic field within 2-4 days after birth. M2 (second molars) which begin to calcify about 4 days after birth showed markedly different behaviour. The stimulated M2 tooth germs showed markedly higher values in uptake of calcium and inorganic phosphate and the researchers suggested that a parallel could be drawn between their work and that of Bassett's Beagle dog experiments. They illustrated this graphically to show the resorption of extraction sites plotted against time, both with and without stimulation.

van der Kuij et al. (1978) also studied the effect of a pulsing electromagnetic field on the extraction wounds of Beagle dogs. The wounds were studied during a stimulation period of 26 weeks and again after a follow-up period of one year (van der Kuij, Vingerling, Sillevis Smitt, de Groot and de Graaff, 1985). The experiments demonstrated a positive effect of the stimulated field on bone resorption, i.e. less resorption than expected. However this led to the need to evaluate the parameters of field strength, repetition rate and pulse shape of the generated fields and demonstrated that the nature of the stimulation mechanism was unclear.

van der Kuij et al. (1985) set up a further experiment involving sixteen female Beagle dogs. Dividing the dogs into two groups, they assessed bone resorption at extraction sites of the 3rd and 4th lower teeth. The dogs' jaws were stimulated using detachable bridges fixed to crowns with precision attachments. The precision attachments also served to ensure that radiographs could be obtained in a reproducible position by attaching the films to be exposed in the same position on successive occasions. Like the observations on human subjects (Bassett et al., 1974), it was apparent that immediately after extraction there was a period of some 4-6 weeks, without stimulation, during which time there was rapid resorption. This was followed by a period when resorption continued at a much slower rate. With stimulation however, the initial resorptive period was much slower and there was less resorption, indeed, there appeared to be a period of apposition. After a time, resorption continued at about the same rate as in unstimulated animals but, because the initial amount of resorption was less, the stimulated animals were always ahead in terms of their residual bone mass, compared to the unstimulated controls.

In addition to evaluating resorption on serial radiographs by expressing bony changes in square millimetres, a mucosal index system was also used to score the state of health of the mucosa beneath the bridges. To verify the apparent clinical picture of the mucosa, the microbiological flora of the soft tissues of some of the dogs were evaluated and classified into morphological categories according to Listgarten and Helden (1978).

The results of this experiment are most interesting in that although the authors originally designed their experiment to assess two separate fields, differences were noted in three fields, i.e. although the contralateral fields in the stimulated animals were not expected to show any differences, they did. These changes, it was suggested, were due to an indirect effect of the stimulation on the microbiological flora, particularly on the spirochete population, due either to a direct effect on the saliva or because of some central effect. They did not postulate what the "central effect" might be but presumably they were referring to an effect mediated through the nervous system and/or an hormonal effect.

THE CHANGING BEHAVIOUR OF THE TONGUE

Although this study is concerned primarily with the anatomy of the mylohyoid ridge and its neighbouring structures, it is necessary to consider functional aspects of the oral tissues as well. The tongue, in particular, plays an important role in the success or otherwise of prosthetic treatment: the following section expands on this topic.

The tongue fills the space available within the oral cavity and performs many functions both with the mouth closed and opened. During swallowing and nasal breathing the tongue seals off the oral cavity. Indeed, lack of this sealing efficiency greatly handicaps swallowing in that it prevents the generation of a pressure gradient to assist the backward propulsion of the food bolus into the pharynx.

Infant tongue behaviour

In the new-born infant no teeth are present within the oral cavity, the surface of each jaw being covered with a gum-pad beneath which lie the developing teeth. At rest the tongue lies between the pads with its lateral and anterior borders contacting the cheeks and lips. At times it protrudes from the lips quite comfortably and infants gain great delight from the sounds they can generate, with a wet tongue, in this posture.

The tactile sensitivity of the tongue and lips of the neonate is remarkable. Until the infant develops tactile sense in the fingers, the lips and the tongue serve to relay information regarding the physical properties of any object encountered. Very early in life, babies will put to their mouths any substance that can be conveyed there. It is not that they necessarily enjoy "eating" anything that they can pick up, it is simply that they are learning to appreciate different textures, temperatures and, of course, flavours, though occasionally the latter may be unsavoury. In a sense the tongue and lips are acting as the infant's eyes and, unlike the adult who first examines an unfamiliar object with the eyes then gains more information by handling it, the infant relies on the tongue and lips to convey to it the information required. Gradually, by trial and error, it progresses to the stage of being capable of making a value-judgement and what is placed in the mouth is a result of a much more selective process. The acute sensitivity of the lips and tongue remains throughout life.

In the newborn child, the tongue helps to maintain the resting relationship of the jaws and during suckling and swallowing adopts a quite distinct and characteristic position. At rest the gum pads are held apart by the lateral borders and the tongue tip is held against the lips. The infantile swallowing pattern is closely associated with suckling and during this exercise the tongue remains in close apposition with the lips and between the gum pads ensuring an effective seal between lips, tongue, cheeks and gum pads. Stabilisation of the mandible is affected by the synchronous relationship of these structures. The buccinator muscle, which at this stage in its development is attached high on the developing alveolar processes, displays marked activity during the infantile swallow, whilst the mandibular elevator muscles, which play a prominent role in normal mature swallows, show minimal activity (Gwynne-Evans, 1951). Presumably the mylohyoid muscles, together with the submandibular glands, both of which are also related high up on the developing alveolar process in early life, play a different role during the infantile swallow than that exhibited by them later on. Their role however must remain speculative in the absence of any published information.

Before the teeth erupt, the tongue, as part of a very active sensory perceptual system, performs in a more forward position. The oral functions in the neonate are guided primarily by tactile stimuli from the lips and tongue (Moyers, 1988). As the incisors erupt, tongue posture changes to the more mature posterior position as mandibular growth downward and forward increases intraoral volume. The alveolar processes enlarge vertically and the jaws lengthen, with an increase in intraoral volume allowing for comfortable accommodation of the tongue within the erupted teeth. These sequential series of changes in posture and behaviour move from anterior to posterior locations and the reflexes controlling posture and function become more complex with eruption of the teeth, establishment of occlusion, masticatory patterns and development of speech.

As the dentition develops, the occlusal movements particular to the individual are learned in stages as the nervous system and the orofacial and jaw musculature mature concomitantly.

When the incisors erupt, at about six months of age, a more precise opening and closing movement of the jaws occurs together with a more retracted tongue position. This is the beginning of the learning of mastication. True chewing movements start later as the first molars erupt. At the same time a more mature swallow develops and the tongue functions within the confines of the teeth. The orofacial muscles (supplied by the seventh cranial nerve) slowly abandon their role during suckling and swallowing as they begin to learn the complicated role they must play in the delicate and precise movements involved with communication - speech and facial expression. At the same time the fifth cranial nerve muscles take over the role of stabilisation of the jaws. Synchronisation with the facial musculature, jaw muscles and the tongue during mastication, speech and swallowing becomes very complex and results in a myriad of well-tuned reflexes.

By approximately fifteen months of age the mature swallow is fully established, i.e. the teeth are usually together, the mandible is stabilised, the tongue tip is held against the palate above and behind the incisor teeth and there is minimal contraction of the lips.

Throughout life the tip of the tongue remains a very sensitive organ of the body. Any unusual event in the oral cavity is immediately detected by the tongue and the increased activity of the tongue tip can be a source of irritation. Everyone has experienced the irritation and increased activity of the tongue in detecting, then attempting removal of, a morsel of food wedged between the teeth. All relaxed activity seems to cease until the morsel is dislodged.

Tongue changes after tooth loss

When a tooth is removed the tongue tip relentlessly finds it way to the socket and for some days, and even weeks, continues to play in and around the defect. After a period this agitation abates and the tongue appears to settle down. However the loss of a tooth interferes with the oral sealing mechanism and the tongue changes shape to compensate for this. The shedding of deciduous teeth is a good example of this behaviour.

When the deciduous incisors are shed the tongue tip protrudes through the resulting gap during swallowing to effect a seal with the lips. During speech it escapes through the space in an attempt to articulate sounds otherwise produced by the interplay between the upper and lower incisors. This results in a temporary speech defect or lisp. This changed tongue behaviour in the infant is normal and transitory, since the tongue reverts to its more usual position when the permanent incisors erupt. Should a deciduous incisor be lost before its usual time of shedding however, the resulting tongue thrust becomes a well established phenomenon and can upset the normal sequence of events which should occur later when the permanent incisors are ready to erupt. Delayed or non-eruption can ensue as well as a difficult to treat defect in speech.

When posterior teeth are lost in the adult the changes in tongue behaviour follow a similar pattern. Unfortunately it is usually not until many posterior teeth are missing that both the patient and the dentist are tempted to influence the situation, by which time irreversible behavioural habits may have been established.

If only one molar is removed, compensation is swift; carried out with the minimum of adjustment; in time, the loss will hardly be noticed by the patient or his professional adviser and will, in all likelihood, cause no other problems worth mentioning. Even if four of the permanent molars are removed - a common procedure in the case of the third permanent molars - no disruption of "normal" performance or function would be expected (Fig. 6a). The removal of the four first permanent molars was commonly advocated some years ago. Provided this was done early enough in the teenager to allow the second and third permanent molars to erupt into contact with the premolars and occlude effectively with their antagonists, this "treatment" was considered to be quite acceptable. This is not so, however, when molar teeth are removed in a haphazard and imbalanced way, i.e. unilaterally. The compensation in these cases is what leads to much more serious problems later on, unless the resulting space is restored fairly quickly after extraction. Unfortunately restoration of these defects is often not achieved for financial reasons, inconvenience or ignorance; it is at this point

Fig. 6a. Prior to posterior tooth loss the posterior sublingual space is not disrupted. Alginate is unsupported and has flown freely into the space which ,as yet, is not changed. (see also fig.11b).

that complex and irreversible changes begin to occur which, insidiously, lead to a life of dental disruption.

When one or more molar teeth are removed haphazardly from a dental arch which is otherwise mature and has, over a period of time become established as a major component of normal function, the tongue and other related structures behave differently. As usual, immediately after the extractions, the tongue tip pursues its inquisitive search of the denuded arch and ultimately loses interest. The tongue's control of the food bolus then changes to avoid allowing portions of food to enter the space. Gradually the lateral wall of the tongue, alongside the space, becomes aware of the defect and attempts, whilst still fulfilling its usual requirements, to block off the space. In a short time not only is the space filled during mastication and bolus control, but also during swallowing and at rest. The soft tissue next to the defect enlarges to allow it to readily fill the space when required and furthermore the hypertrophy of tissue is such that the tongue reaches the cheek to again ensure an efficient seal during deglutition. Because the deep portion of the submandibular gland is so intimately related to the tongue and the mylohyoid muscle, both of these structures are inevitably drawn upward and outward into the space as well. This is partly because of the physical effort made to block off the defect but is also due to the sub-atmospheric pressure generated during swallowing - occurring usually about 600 times per day. Eventually a situation exists where, at rest, a substantial portion of the tongue, together with submandibular gland, comes to lie quite comfortably *on* the residual edentulous alveolus, rather than medial and inferior to it, and the mucous membrane covering these tissues contacts the cheek (Fig. 6b).

This phenomenon occurs on either, or both, sides of the mouth depending on how many, and where, teeth are removed. It occurs more commonly and more obviously when lower molar teeth are removed. With

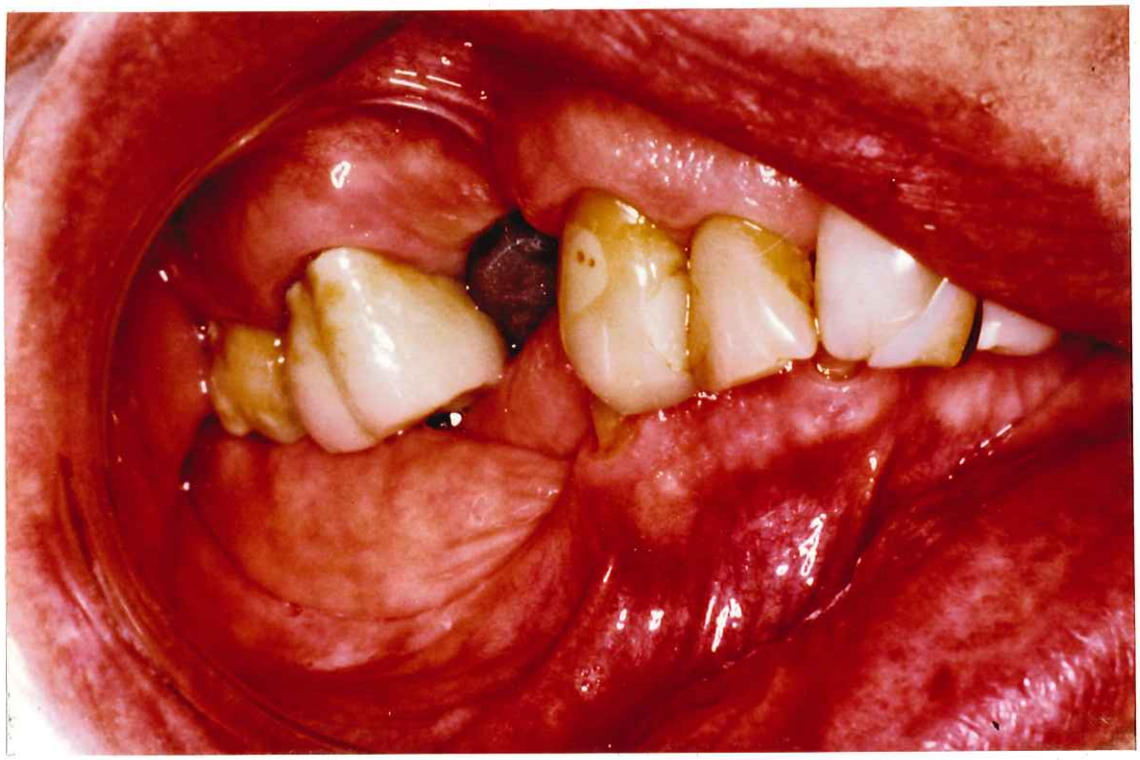


Fig. 6b. Displaced gland now lies over the edentulous ridge. Note other features of early tooth loss.

advancing mandibular resorption, the tongue "collapses" and moves laterally into the space created by the missing periodontium. In a sense it attempts to function like the missing molars and create an oral seal at the same time.

As more posterior teeth are lost effective chewing ability diminishes. The bolus has to be aligned further forward on the remaining arch and teeth which are not normally used in chewing may be required to perform in an unusual manner. As long as just one pair of opposing molar teeth remain, nearly normal chewing patterns may continue but with all molars removed, chewing is attempted on the canine and premolar areas of the arch. The success of this exercise depends on the degree of jaw movements by the anterior teeth and particularly the canines. A marked overbite of either will limit grinding ability and probably encourage the patient to seek professional help (Fig. 7a). If, however, the patient does manage to "chew" on the front teeth (and it seems that this is more likely when the overbite and overjet is small), wear and tear on these teeth is the likely outcome. However the consequences of the latter process take time to manifest themselves (Fig. 7b).

At first there is a "wearing in" period where tooth surfaces are ground in to a new chewing pattern. Depending on the adjustments which are made necessary, the jaws may be forced to perform further forward than usual and this causes stress on the temporomandibular joints. In time, joint changes and/or pain associated with the joint, may ensue. The wear on the tooth surfaces progresses to the "wearing out" phase when dental intervention become inevitable (Fig. 8a). By the time this period is reached, the overall restorative problems may be formidable (Fig. 8b).

The most likely complaint by the patient at this stage is that the appearance of the upper anterior teeth is unacceptable. Repairing the upper anterior teeth only is useless without also making replacements for

Fig. 7a. Marked overbite of anterior teeth. Severe wear on canines.

Fig. 7b. Severe wear and tear resulting from edge-to-edge anterior tooth relationship after loss of posterior teeth.

Fig. 8a. The wearing out phase. Note the tongue posture.

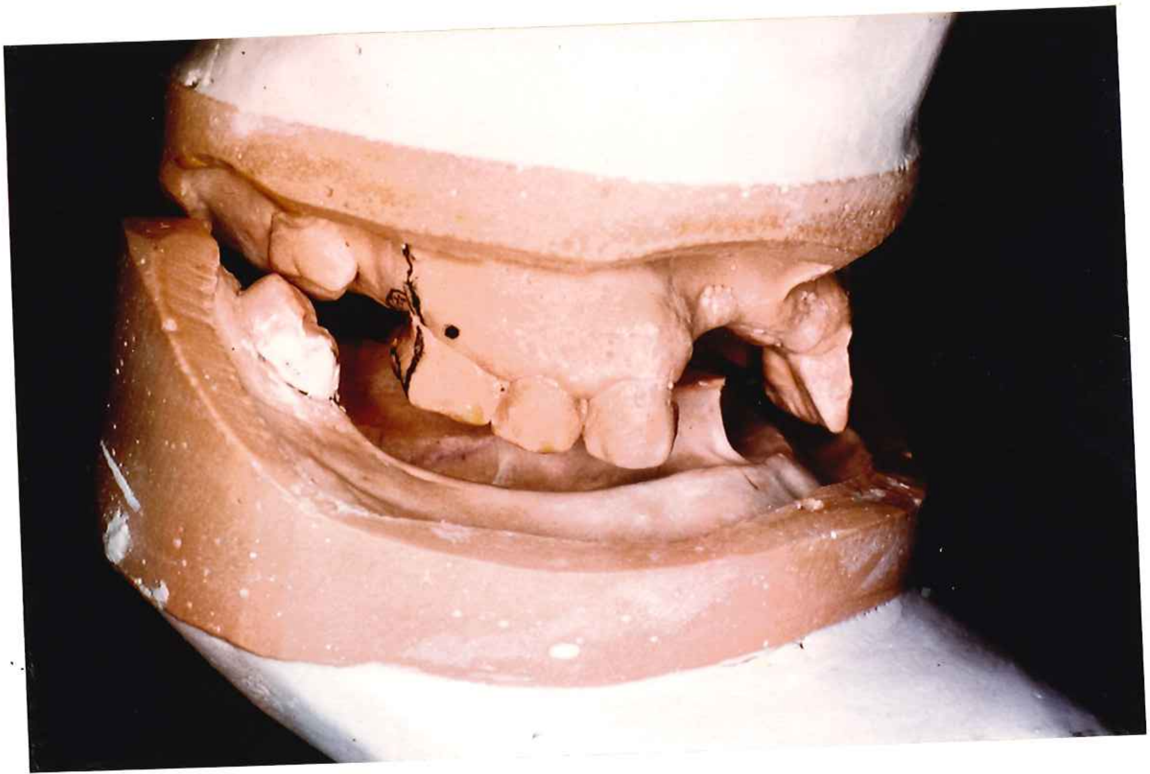


Fig. 8b. Casts of patient shown in Figs. 9. demonstrating formidable restorative problems.

the missing posterior teeth (Fig. 9a). Theoretically, the latter should recreate an acceptable vertical height and restore the posterior support for the jaws, thus improving chewing ability (Fig. 9b). Unfortunately changed tongue behaviour may now preclude the construction of a suitable prosthesis. A hyperactive tongue may prevent the making of an appropriate impression of the posterior lingual sulcus and the resulting prosthesis will be poorly extended into this area, i.e. the base of the denture will be too small and will probably have no lingual flange. It will therefore offer little support and no resistance to lateral displacement. If the patient manages to wear such a denture they will, in all probability, continue to use their front teeth for "chewing" and progressive deterioration is inevitable whether the denture is worn or not.

Fig. 9a. Profile of patient shown in Fig. 8b. prior to restoration of posterior support.

Fig. 9b. Profile of same patient with corrected posterior support.

INSIDIOUS CHANGES IN THE ORAL CAVITY FOLLOWING TOOTH LOSS

The progression, or more accurately regression, from the loss of posterior maxillary teeth to the provision of a full upper denture is a common event. The reason that it occurs with such frequency is probably because in many cases it appears to be a practical and relatively harmless proposition which, at least for the foreseeable future, will satisfy the needs of the patient. At this stage of dental deterioration the patient is often more concerned with their appearance and will look for a solution that avoids the use of a prosthesis in the lower jaw and which falls within the constraints of a stretched budget. By the time the remaining mandibular teeth are removed, therefore, a number of problems may have developed which legislate against success in the attempt to provide satisfactory full dentures for the patient.

The loss of posterior teeth often leads to a compounding sequence of events:

1. Changes in tongue behaviour.
2. Changes in mandibular posture and function.
3. Bone loss, particularly in the lower jaw.
4. Overeruption of the teeth and their supporting tissues, particularly upper.
5. Damage to teeth further forward.
6. Possible joint-associated disorders.
7. Further loss of bone.
8. Edentulousness.

It would not be unreasonable to suggest that as this sequence has occurred with such monotonous regularity in so many patients, the phenomenon could be described as a syndrome.

Kelly (1972) attempted to do this when he reported the changes caused by a mandibular removable partial denture opposing a maxillary complete denture. He described five changes, referred to as the Combination Syndrome, which occur in these circumstances particularly when only anterior teeth remain in the lower jaw:-

1) Loss of bone from the anterior maxillary ridge (Fig. 10a).
2) Overgrowth of the maxillary tuberosities (Fig. 10a).
3) Papillary hyperplasia in the hard palate (Fig. 10b).
4) Extrusion of the lower anterior teeth.
5) The loss of bone under the partial denture base.

Saunders, Gilles and Desjardins (1979) acknowledged the five destructive changes described by Kelly and suggested that six further changes should be taken into account when considering the "Combination Syndrome", viz. 1) loss of vertical dimension of occlusion, 2) occlusal plane discrepancy, 3) anterior spatial repositioning of the mandible, 4) poor adaptation of the prostheses, 5) epulis fissuratum, and 6) periodontal changes.

An inordinately large number of patients with difficulties associated with full dentures give a similar history of the events leading to edentulousness to those described above (Shen and Gongloff, 1989).

As mandibular resorption proceeds, lower denture stability is reduced and bony prominences, such as the mylohyoid ridge, become more closely related to the prosthesis where they may cause discomfort or pain. It is not surprising, therefore, that some form of surgical modification to the tissues may be necessary prior to the construction of successful prostheses. By understanding all of the insidious changes that may occur in the oral complex following tooth loss, it is frequently found that simple surgery may be all that is required to obtain a satisfactory long-term prosthodontic result (Fig. 11a).

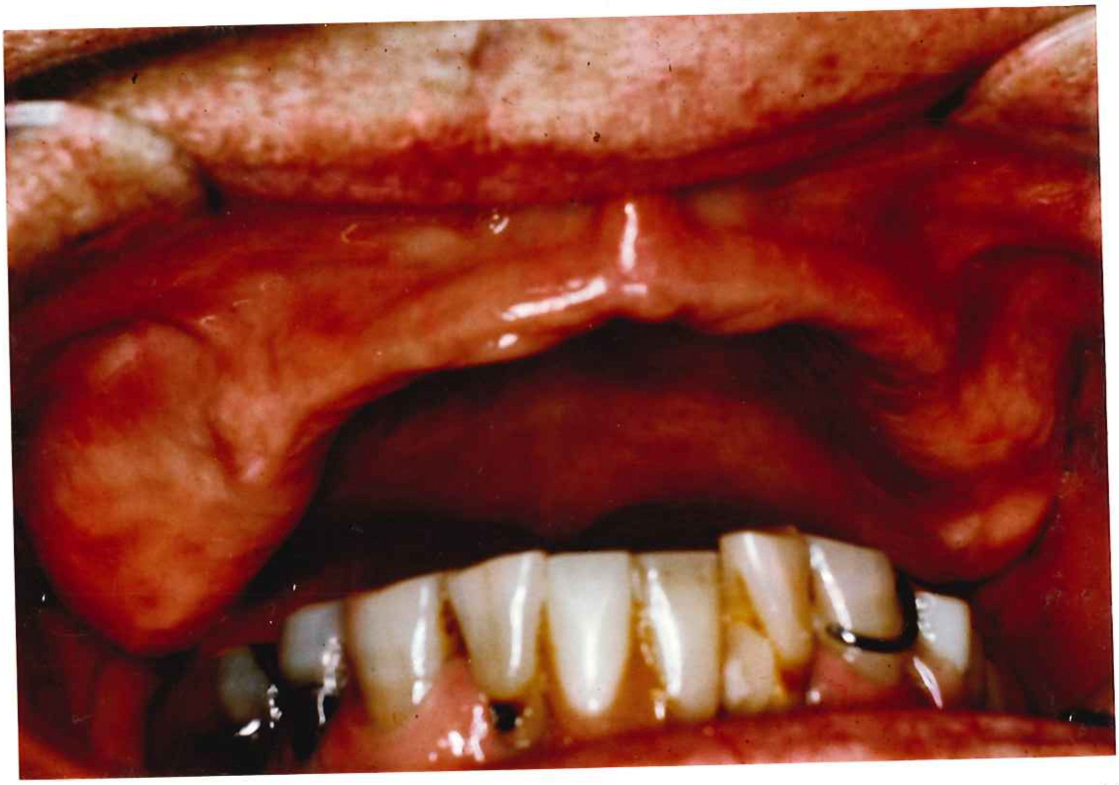


Fig. 10a. Loss of bone in maxillary ridge and overgrowth of patient's tuberosity complex on right side.

Fig. 10b. Typical papillary hyperplasia of palate.

Reference has already been made to the other changes which accompany bone loss. The obvious changes are changes in behaviour patterns. For example, jaw reflexes lose sensory input from the network in and around the periodontal ligament and must be served by whatever sensory input they can foster from other sources. The less obvious changes are the rearranged physical relationships and behaviour of the structures intimately related to the jaws (Figs. 11a, 11b). Not only do the various tissue masses change in their relationship to one another but they may also change shape as a result of this, and their changing role, in the attempt to perform "normal" functions.

Because a denture is not attached to the jaws, its potential for movement is dependent on its stability and retention. During chewing a powerful displacing force acts on the lower denture to displace it downward, outward and forward on the working side. Rotation of the denture occurs around a fulcrum situated lingually in the region of the canine and premolar and the non-working side tends to rise. The only resistance to this displacement is the lingual flange on the working side and to a lesser extent the buccal flange on the non-working side. The more well formed the ridge, the greater the resistance offered.

Fig. 11a. Insufficient vertical space at rest. Simple surgery required.

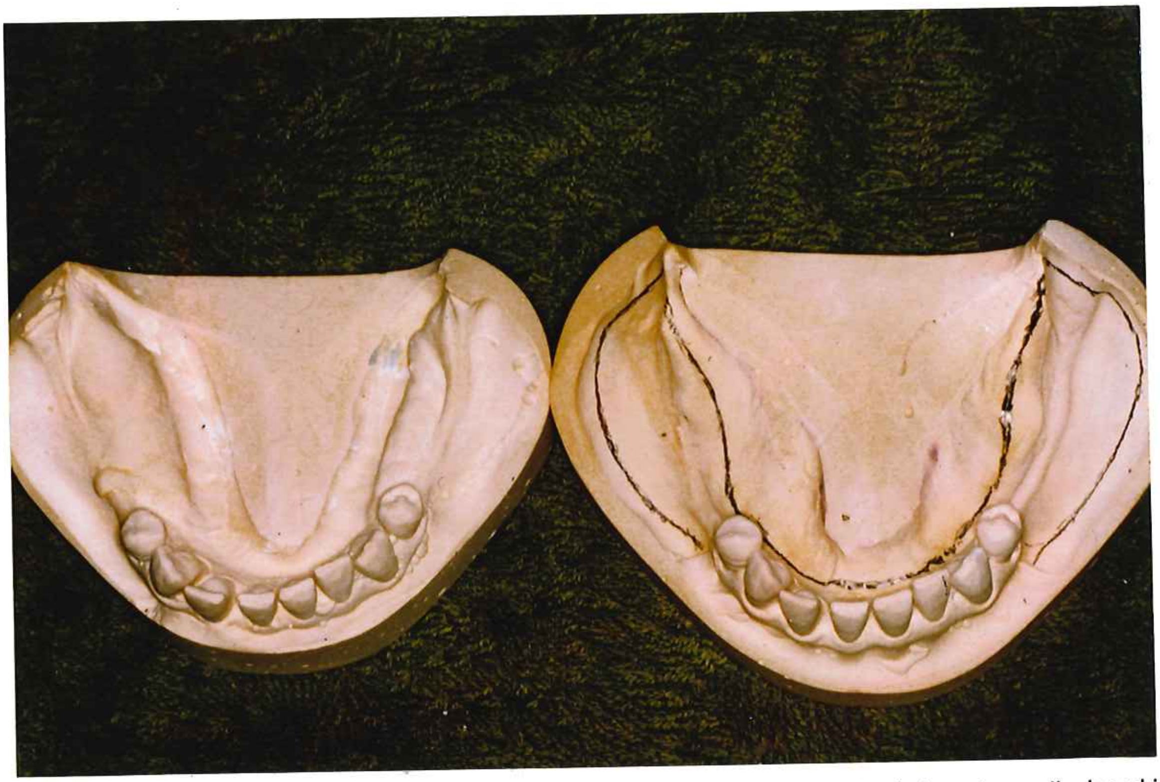


Fig. 11b. Cast on left records submandibular glands lying over ridge. The glands have been displaced in cast on right, to record true outline of lingual sulcus.

SECTION TWO

SURGICAL METHODS FOR REDUCING DISCOMFORT FROM A PROSTHESIS IN THE EDENTULOUS MANDIBLE

INTRODUCTORY COMMENTS

The various destructive processes described, including the wearing of dentures over many years, can lead to a situation where the remaining tissues provide an inadequate foundation for new prostheses. Inevitably surgeons are requested to devise approaches which may reduce the difficulties for both patient and dentist. This has led, over the years, to the development of the discipline of pre-prosthetic surgery.

The introduction of general anaesthesia using nitrous oxide in 1844, soon followed by ethyl ether in 1846, heralded the era of painless dentistry. Shortly after the introduction of general anaesthesia, Willard (1853) advocated the reduction of alveolar margins and interdental papillae after dental extractions. This hastened healing and permitted earlier construction of artificial dentures.

For nearly a century very few advances were made beyond smoothing lumps and bumps. Skin and bone grafting to the jaws and face were introduced during World War I. Between the two World Wars sulpha drugs were introduced and contributed to the advance in surgical techniques during World War II. Penicillin contributed to more complex innovations being introduced towards the end of the Second World War. Surgical reconstructive techniques had advanced greatly by the time the Korean and Vietnamese conflicts took place and were further modified and improved out of the necessity to deal with the horrific injuries of these encounters.

Pre-prosthetic surgery as a reconstructive service had its beginnings with a report by Kazanjian (1924) on labiobuccal vestibuloplasty procedures (Fig. 12). Techniques advocating extension of the lingual sulcus were described by Trauner (1954), Caldwell (1955) and Obwegeser (1959) (Fig. 13). The technique of vestibuloplasty increases the relative height of the alveolar ridge and, as this increases the potential stability of a denture

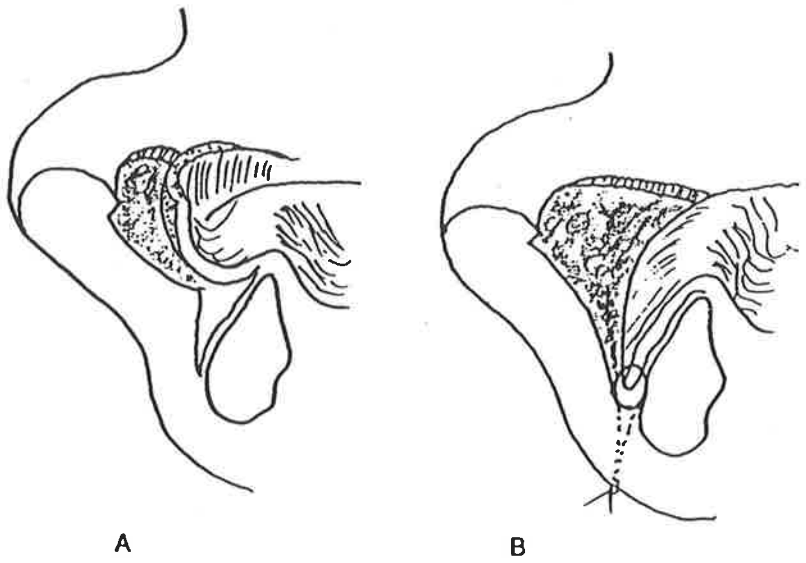


Fig. 12. Kazanjian's technique of labial sulcoplasty. The flap raised from the inner lip at A is anchored to the deepened labial sulcus by a rubber catheter held in place by external sutures (B). The denuded lip is allowed to heal by granulation.

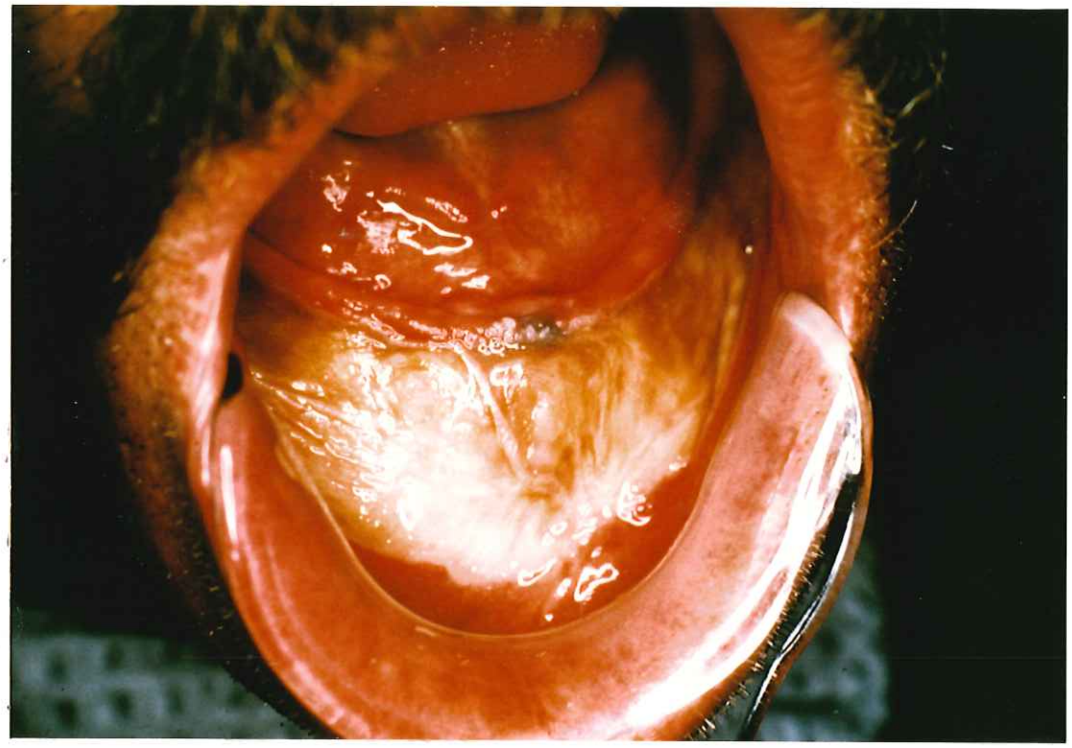


Fig. 13. Split skin graft sutured to periosteal surface (after Schuchardt).

base, it was not long before surgeons devised methods to increase the absolute height of the ridge crest.

Bone and rib grafting to the mandible followed on Boyne's research in bone healing and repair (Boyne and Kruger, 1962; Boyne, 1966) and subsequently Davis, Delo and Weiner (1970) and Terry, Albright and Baker (1974) advanced the scope of reconstruction augmentation procedures.

More recently the iliac crest has been used as a donor site for bone grafting to the jaws. The use of this donor site is growing in popularity, particularly since microsurgical techniques now allow for the suturing of fine blood vessels. Grafts based on the deep circumflex iliac artery were described by Bitter (1980) following the successful removal of an oral carcinoma involving the mandible and repair of the defect with an iliac crest graft with its blood flow maintained by microsurgery.

The complexity of surgical procedures which have evolved over the past 60 or 70 years have been provoked by the changes that take place in the jaw bones following removal of the teeth. The severe atrophy which often occurs leads to difficulties in providing satisfactory prostheses.

Since the late 1950s authors throughout the world have been reporting new techniques for improving badly resorbed mandibles in various surgical journals. For the most part these techniques aim at increasing the available ridge form by augmentation. This is achieved in two ways. Firstly, by deepening the labial, lingual or both sulci - so-called relative augmentation. Secondly, by reshaping the remaining bone either by splitting the body of the mandible, rearranging the segments and grafting bone, cartilage or alloplastic grafts into the intervening spaces to encourage consolidation, or by grafting directly onto the remaining bone. In the latter examples the procedure is referred to as an absolute augmentation.

RELATIVE AUGMENTATION

The earliest attempts at augmentation were by various means of vestibuloplasty. Usually the labial vestibule was deepened by reflecting the mucosa below the level of its normal depth and allowing secondary epithelialisation to repair the defect. This method was described in the same year by Rumpel (1916), Gamzer (1916) and Sjaba (1916), quite independently of each other. Relapse occurred with this procedure despite splints being placed over the periosteal surface. The relatively poor reputation that this method suffered was confirmed by Spengler and Hayward (1964) following their work on wound healing in dogs. Knolle and Pfeiffer (1966) also documented the considerable relapse that occurs with this method.

The submucosal vestibuloplasty enjoyed popularity for some time but, as pointed out by Obwegeser (1959), it carries the risk of damage to the mental nerves during the blind dissection of the submucosa to release tissue.

Moskovitch (1916) was the first to report the use of skin-grafts to improve the denture bearing area, by using an extraoral submental approach to place the graft. This method was repeated soon after by Esser (1917). The procedure was improved by Pickerill (1919) who used the intraoral approach and advocated a stent to secure the graft in place. Gillies (1920) also used this method and applied it as well to maxillary surgery as did Kilner and Jackson (1921) shortly thereafter. It was not until Schuchardt (1952 and 1959) pointed out that the periosteal surface, not the soft tissue bed, should be covered with skin and the free margin of the mucosa should be sutured to the periosteum, deep in the newly created vestibule, that graft contraction was better controlled (Fig. 13).

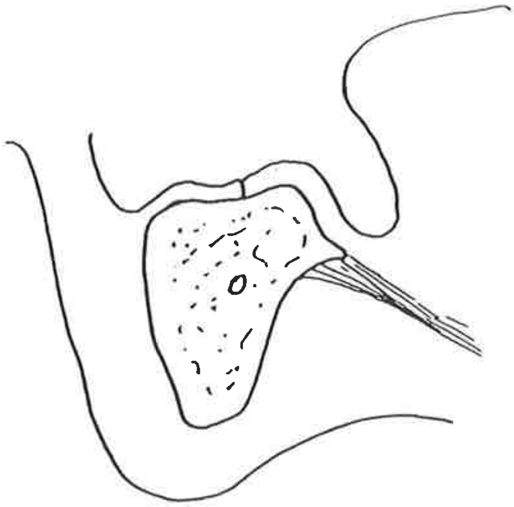
Lingual sulcoplasty

As the lower denture tends to be displaced downwards, outwards and forwards during chewing it requires a lingual flange of sufficient vertical extension to resist this displacement. During function, particularly swallowing, the floor of the mouth rises as the supra-hyoid muscles contract and frequently the anterior and posterior lingual sulci are obliterated in cases of severe alveolar bone resorption. Even when there is sufficient depth for an adequately extended lingual flange the mylohyoid ridge may be sharp and prominent and moderate pressure may be sufficient to cause pain during function.

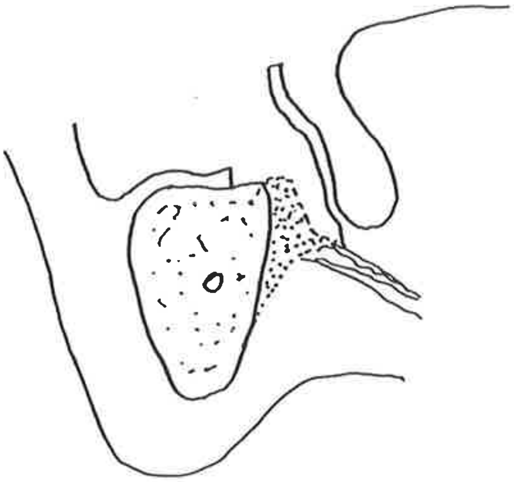
Genial tubercles can also prove troublesome and at times are particularly prominent. This is due mainly to severe resorption but as well it is partly due to calcification of the muscle insertion causing elongation of the tubercle. Reduction of the genial tubercles together with lingual frenotomy and transplantation of the superficial fibres of the genioglossus muscles was advocated by Cooley (1952) to overcome this problem. He pointed out, not surprisingly, that stripping of the entire genioglossus muscles would lead to troublesome postoperative problems, including difficulties with speech and swallowing, due to posterior retraction of the entire muscle mass under the tongue. He suggested that, should the entire muscle mass be detached, it should be reattached lower down to an intraosseous wire placed horizontally through the mandible. The wire is then removed about six weeks postoperatively.

Most commonly it is the posterior lingual sulcoplasty which is performed. Many procedures have been described over the years but essentially they are all modifications of the procedures outlined by Trauner (1954), Caldwell (1955) and Obwegeser (1959) (Fig. 14).

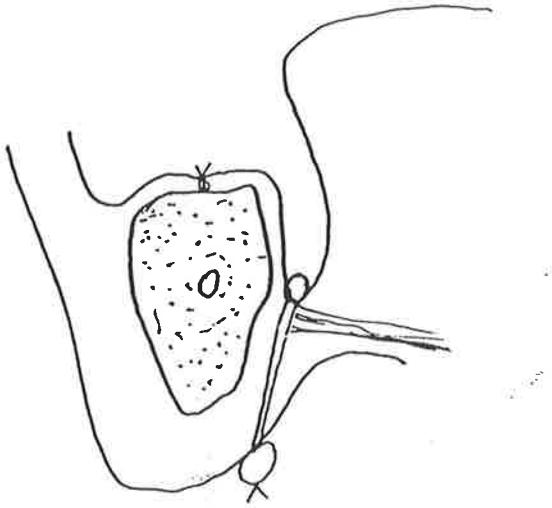
Trauner described a method of deepening the lingual sulcus without bone removal. This was accomplished by incising the mylohyoid muscle



Incision in centre of ridge.



Mucoperiosteum peeled away lingually together with mylohyoid muscle. Mylohyoid ridge removed.



Sulcus depth maintained with anchor suture penetrating beneath chin in submandibular fossa.

Fig. 14. Caldwell's procedure of lingual sulcoplasty.

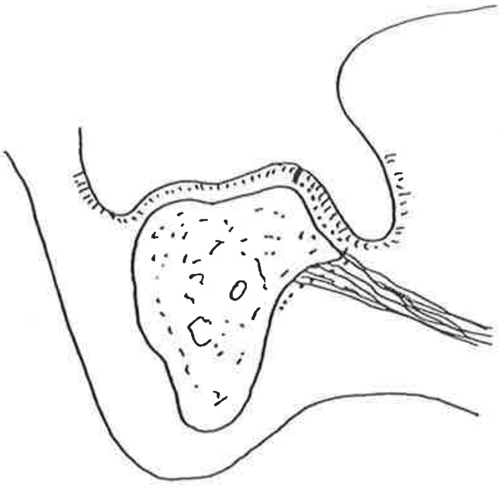
fibres and deepening the sulcus by supraperiosteal dissection. The severed lingual tissues and cut muscle were then held down by sutures emerging beneath the mandible and held in place with buttons. The intact exposed periosteum was then either left to granulate or covered with a split skin graft held in place with a stent (Fig. 15).

Caldwell (1955) described a subperiosteal procedure whereby the mylohyoid muscle was peeled away from the bone together with the periosteum. The exposed mylohyoid ridge was then removed and the bone smoothed. In the procedure which Caldwell originally described (see Fig. 14, p. 58). the new depth of lingual sulcus was maintained with rubber tubing secured by percutaneous sutures tied around cotton wool rolls beneath the mandible.

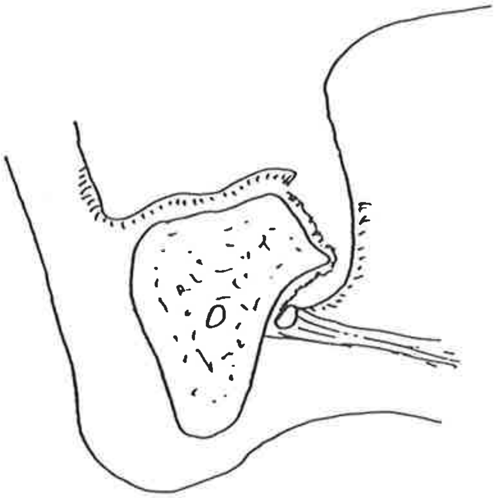
A method of combining a lowering of the floor of the mouth, similar to Trauner's (1954) procedure, and a skin-grafted labial vestibuloplasty was described by Obwegeser (1963) and MacIntosh and Obwegeser (1967). After deepening the labial and lingual sulci, a stent made preoperatively was extended with suitable thermoplastic material to the new sulcus depth. The stent was then draped with a split-thickness graft and wired into place for about 10 days (Fig. 16).

ABSOLUTE AUGMENTATION

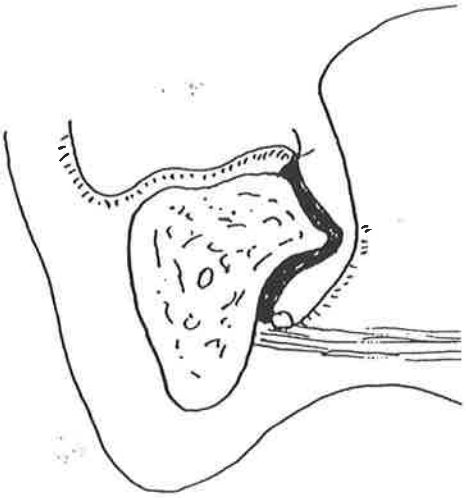
Despite the many techniques employed in an attempt to improve the grossly resorbed mandible, the major problem of bone loss is not overcome. Prostheses tend to be very bulky and, as the occlusal surface tends to be a long distance from the fitting surface, there is a large potential of instability inherent in such a prosthesis. A substantial residual ridge of good proportion which allows for an adequate interalveolar space seems to be the shape most desired for the construction of a stable and retentive lower denture. This requirement of prosthodontists has led surgeons to devise



Incision just above mylohyoid ridge.



Sulcus deepened by raising the mucosa, incising the muscle, but leaving the periosteum intact.



Sulcus depth maintained with through-skin anchor. Split skin graft to denuded bone surface. The resulting bony undercut was thought to have a prosthetic advantage.

Fig. 15. Trauner's procedure with split skin graft.

Fig. 16. Combined lowering of floor of mouth and labial vestibuloplasty (after Obwegeser,1963).

surgical techniques to increase the height of the resorbed ridge by one means or another - absolute augmentation.

It is not just for prosthodontic reasons however that bone-grafting is considered necessary. Fractures of the grossly resorbed edentulous mandible are notoriously difficult to treat successfully. Bruce and Strachan (1976) and Van de Mark, Weinberg and Zosky (1969) suggest that when the remaining mandibular body is less than 10 mm in height, the danger of fracture following only slight trauma is a matter which must receive serious consideration.

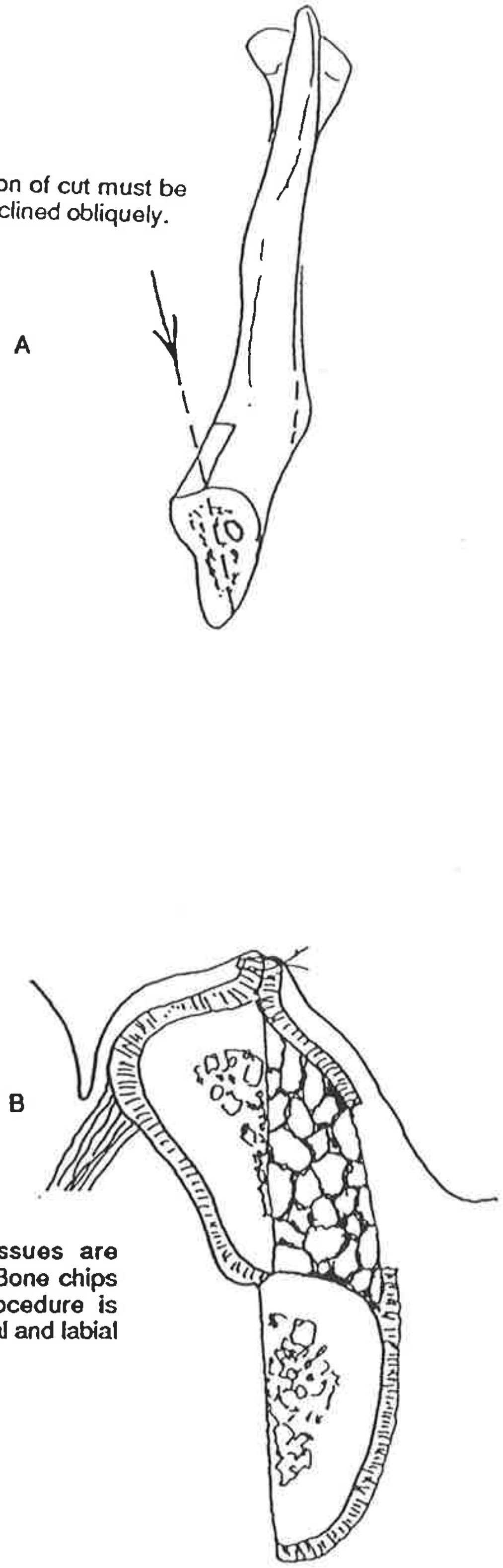
Early attempts to augment the mandible relate to the use of autogenous iliac crest bone. Clementshitch (1948), Thoma and Holland (1951), Schmid (1954), Gerry (1956), Lane (1958), Thoma (1958), Schuchardt and Frolich (1959), Celesnik (1963), Obwegeser (1967) and Steinhauser and Obwegeser (1967) all reported favourable results initially, but long-term evaluation was lacking. It is clear now though that rapid resorption of the graft was inevitable. Five cases of non-decorticated iliac grafts over a period of nine months to three and one-half years were reported by Wang and Waite (1976). At 6 months there was 28 per cent resorption, at 12 months 45 per cent resorption, at two years 78 per cent resorption and at the third year, 89 per cent.

A technique to overcome the problems of rapid subperiosteal graft resorption, using a submandibular approach for the portal of the graft, was described by Curtis and Ware (1977). They reported five cases where the iliac bone grafts were placed in three pieces interposed with cancellous particles. They illustrated their results with panoramic radiographic tracings and reported a retention of over 50 per cent between 15 to 64 months. A report of 12 cases using completely decorticated ilium was reported by Fazili et al. (1978) where the average resorption after 36 months was 92 per cent.

The relatively disappointing results following direct grafting to subperiosteal surfaces encouraged surgeons to devise methods of augmenting the mandibular body whilst retaining an intact periosteum and viable blood supply to the region. Amongst them was Harle (1975) who published a preliminary report describing a method of vertically splitting the mandibular body between the mental foramina, prising open the two segments and packing autogenous bone fragments between the two "halves" - the so-called vertical or visor osteotomy had arrived (Figs. 17a, 17b). The "sandwich" osteotomy, first described by Schettler and Holteman (1977) was based on similar principles to that of the visor osteotomy, both operations designed to ensure that the blood flow to the osteotomy sites was maintained and that the periosteal covering to the bone remained intact.

Both of the procedures mentioned involve pedicled bone flaps and the decision regarding the procedure seems to be based very largely on which side of the Atlantic Ocean the surgeon is situated. However, Peterson (1983) suggested a guide-line for choosing between vertical and horizontal osteotomy. He suggested that if resorption of the ridge is so severe that little or no bone remains above the inferior alveolar canal, then a vertical osteotomy should be performed. As he advised, should a horizontal osteotomy be performed in this situation, the mental nerve is jeopardized as it is subjected to trauma from a denture, causing pain during mastication. He went on to suggest that in the rare circumstance of the mandible being particularly narrow in its buccolingual dimension, then the horizontal osteotomy is the procedure of choice.

After either of these mandibular procedures some type of vestibuloplasty is mandatory and it is claimed that secondary vestibuloplasty can be performed usually before the third month. Peterson and Slade (1977) and Brons, Bosker and Van Dijk (1977) described immediate vestibuloplasty, the former advocating a Kazanjian-type flap based on the



Vertical osteotomy. Direction of cut must be towards lower border and inclined obliquely.

Lingual bone and attached tissues are elevated upwards (Visor shift). Bone chips pack the labial shelf. The procedure is followed sometime later with lingual and labial sulcoplasties.

Fig. 17. Absolute augmentation.

mobilised anterior bony segment whilst the latter opted for a free piece of buccal mucosa to complete the labial deepening.

Whichever technique is used, the evidence suggests few long-term differences in terms of bone loss, and the outstanding complication, that of damage to the mental nerve, has not been satisfactorily overcome. Lekkas (1977) described a 15 per cent loss of the initial height gained after 18-30 months. Mercier's team (1982) compared different techniques and painted a more gloomy picture in that resorption over 18 months was as much as 34-65 per cent. The resultant nerve damage prompted Lekkas and Wes (1981) to vary the technique by designing the osteotomy around surgical entry to the site from an extraoral approach. Frost, Fonseca and Burkes (1982) and Bailey and Bays (1984) demonstrated long-term nerve disturbance following an augmentation procedure involving exposure and "repositioning" of the inferior alveolar nerve.

Stoelinga, Blijdorp and De Koomen (1985) claim to avoid the problem of nerve injury by completing the osteotomy just anterior to the mental foramen, and augmenting the posterior body bilaterally behind the mental foramina using hydroxyapatite.

Alloplastic Grafts

According to Topazian and Hammer (1971), the ideal material for use in ridge augmentation should be non-toxic, non-antigenic, strong, resilient, adaptable in form, inexpensive, available in sufficient quantity and require a simple surgical technique. Because of the rapid resorption following autogenous bone graft placement, coupled with the necessity to invade a suitable donor site, there has been a constant search for a material which may satisfy the ideals suggested above.

Boucher (1965) described four research projects, reported in the one paper, designed to study the reaction of the tissue to implanted plastics and silicones. Eleven different materials were implanted in thirty-five rabbits and twelve cats. The experiments encouraged him to proceed with the use of Medical Silastic 5392 to which a thinner had been added. Multiple injections of this material were made on 16 human patients. The areas involved were sharp knife-edged residual alveolar ridges, mylohyoid ridges, genial tubercles and mental foraminae. In addition he built out undercut areas and injected material into hyperplastic tissues in both upper and lower jaws. He suggested that the results were most encouraging provided only minimal amounts of material were needed. This technique, however, is not universally acclaimed.

Because of the need to "correct" larger areas of bone, experiments continued with various materials, including metals and acrylics, in solid form. Fitzpatrick (1968) experimented with nine such materials - five forms of silastic, acrylic (both polished and sanded), Vitallium and Teflon felt. All appeared biologically safe and the silastic products had the least tissue reaction. Teflon felt had a remarkable "affinity" for its surrounding tissues and appeared to incorporate easily into the normal matrix of connective tissue or bone. In addition, Teflon felt appeared likely to resist exfoliation when part of its surface was exposed through overlying tissues. It showed a remarkable capacity to "fuse" with the surrounding tissues and in the presence of infection appeared to resist extrusion.

When faced with a flabby edentulous ridge, all operators wish for a method of "hardening" the existing tissues rather than removing them or attempting to build them out. Inevitably therefore attempts were made to increase the firmness and reduce the displacement of this tissue. Laskin (1968) suggested a method of doing this by using a five percent solution of sodium morrhuate and claimed moderate success.

Hydroxyapatite

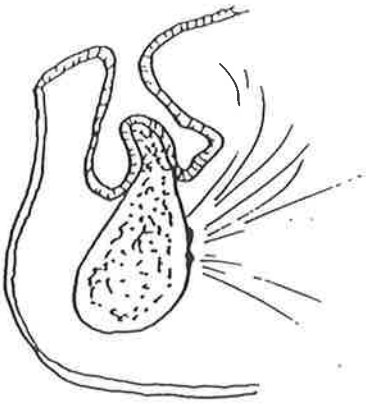
Hydroxyapatite forms the crystalline framework in human calcified tissue. It is readily synthesized from the biogenic carbonate of the sceractinian coral porites and has physical and chemical properties almost identical to the major mineral components of enamel, dentine and bone. Because of its calcium content, it is radio-opaque. It is also dense, non-resorbable and pure. Though expensive, it is readily available both in particle form and in blocks of various size. Commonly the particulate form is mixed with blood or blood and cancellous bone and/or plaster of Paris. The "paste" resulting from these mixtures is then injected into a subperiosteal tunnel using a wide bore syringe (Figs. 18).

Despite many encouraging reports in the literature, notably by Kent et al. (1982, 1983), Block and Kent (1984), Chang et al. (1983), a number of problems are yet to be overcome. It is difficult to maintain an ideal ridge form whilst the organisation of new callous takes place in and around the material. Both porous and non-porous forms have been used, the former giving more promising results as it encourages ingrowth of fibrous tissue.

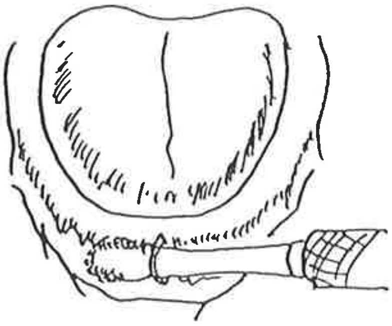
Dehiscence is another problem, particles tending to extrude from the mucosa (Hupp and Tyson, 1985). Similarly the migration of particles into the mental foramina, and other regions where it is unwanted, has proved troublesome (Desjardins, 1985). A further disadvantage is its tendency, once in place, to set very hard when organised and it is difficult to alter.

Many attempts have been made to control the shape of the implanted material and Silverberg et al. (1986) reported on the use of polyglycolic acid mesh to confine particulate hydroxyapatite for augmentation of bone in rats.

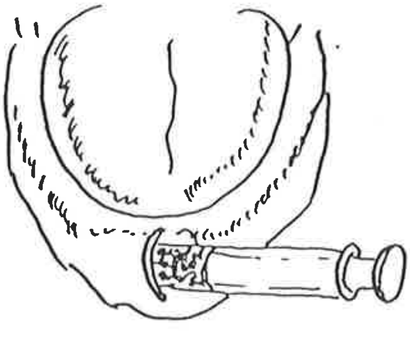
Gongloff and Montgomery (1985) experimented with preformed collagen tubes containing hydroxyapatite and reported on a technique to implant the loaded tubes subperiostally to recontour the ridge. The tubes which consist of bovine collagen (American Biomaterials Corp.), are perforated and of varying diameters, either 5, 8 or 10 millimetre. Three loaded tube sections are placed, one in each posterior segment of the body



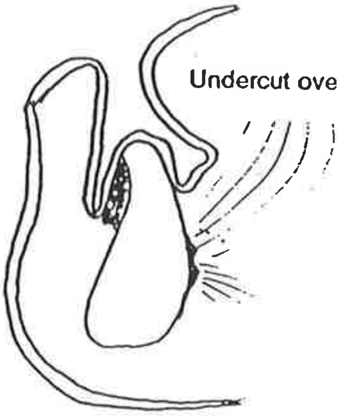
Bony undercut in labial sulcus.



Subperiosteal tunnel through vertical incision.



Particles of hydroxyapatite / bone slurry placed into tunnel with syringe.



Undercut over-packed to allow for shrinkage.

Fig. 18. The principle of packing out undercut ridges. (In this case with hydroxyapatite).

posterior to the mental foramen and one placed in the anterior segment between the two foramina.

Gongloff and Lee (1989) reviewed the results of this method on 20 patients and claimed that 95 per cent of these were prosthodontically successful, in that the prosthodontist reported that the final ridge form following obligatory sulcoplasty was well consolidated, immobile and the of desired shape. However, their patients' evaluations were somewhat different in that 20 per cent (4 patients) rated their experience as unchanged and 5 per cent (1 patient) considered it worse.

A recent publication concerning the use of hydroxyapatite relates to a problem-related classification of resorbed mandibles with a view to the clinician establishing a rational plan of treatment (Zeltser et al., 1989). This contribution to the literature offers little new. The authors however stress that the choices of covering materials should relate to split skin rather than mucosa following the stage two surgical procedure - vestibuloplasty and lowering of the floor of the mouth. They stress also that the cross-sectional shape of the mandibular body following surgery should resemble a comma when viewed as a coronal section and add that when the desired form is created and covered with split-skin, "the keratinised graft is more resistant to forces than non-keratinised mucosa, thus encouraging discriminative forces during mastication" - a statement difficult to comprehend.

Skin as a graft material

Skin, though widely used as a grafting material, is lacking in certain important properties when used in the mouth. This is particularly so when used in pre-prosthetic surgery. The mucosa being wettable and resilient contributes to a border seal. Skin, however, tends to become soggy, may contain hair follicles (the growth of hair in the oral cavity is objectionable) and is also particularly susceptible to fungal infection. Excessive keratinisation is also a drawback Guernsey (1973), Fitzpatrick (1976). A further drawback is the creation of another surgical site remote from the oral cavity. It is not uncommon for the patient to complain of more discomfort from a denuded inner thigh than from the mouth (Fig. 19). Furthermore, scarring of the donor site can ensue and may be disfiguring. Hillerup (1984) reviewed the literature on skin and mucosal graft behaviour in the oral cavity and found that 25 per cent of denture-bearing skin grafts showed pathological changes.

Dermal grafts

Because of the problems associated with skin-grafting and in particular the belief (Donoff, 1976) that it was the dermal layer of the graft which inhibited wound margin contracture, Smiler et al. (1977) used dermal grafting in mandibular vestibuloplasties. They suggested that autogenous dermal grafts are readily available, easily revascularised, viable immunocompatible transplants that inhibit wound margin contracture. They are durable and can be cut in varying thicknesses, since the hair follicles are said to degenerate in time. Re-epithelialisation of the graft is by regeneration of epithelial cells in the remnants of hair follicles and sweat glands. More importantly the cells are claimed to take on the characteristics of the surrounding mucosa instead of retaining the structural characteristics of skin.

The dermal graft is harvested by first raising a split thickness strip of skin (0.012 to 0.014 inch) with a dermatome. This is left attached at one end. The dermatome is disassembled and removed. It is then reassembled and set to remove a narrower strip of dermis 0.015 to 0.22 inch thick. The original pedicled split-thickness skin flap is then returned to its bed and sutured into place. The donor site thus has an immediate physiologic covering (Starshak and Sanders, 1980).

Fig. 19. Donor site (inner thigh) of split skin graft causing continuous discomfort at three months.

Mucosal grafts

Despite the availability of skin and the improvements in its harvesting, mucous membrane remains the tissue of choice as a donor material. Frequently, however, the area to be covered seems far more extensive than the area of readily obtainable mucosa in other sites of the oral cavity.

Cheek mucosa in its full and split thickness forms was used by Propper (1964) and Steinhauser (1969). The palate also seemed an obvious site of harvest and its use was advocated by Hall and O'Steen (1970) and Guernsy (1973). Later, Sanders and Starshak (1975) suggested a modified design of the donor site which eliminated median palatal ulceration and resulted in two large, sturdy palatal mucosal grafts. Shepherd et al. (1975) described modifications to perforate and expand the size of a palatal graft to minimise the area of the donor site (Fig. 20).

Harvesting from the palate can lead to excessive bleeding and is usually accompanied with severe discomfort after healing which lasts many months. Also, many palates are riddled with papillary hyperplasia and this precludes their use Hopkins (1987).

Because of its obvious size, the cheek seems a better proposition. However, there were always fears that closure after removal would lead to problems associated with mouth opening. However, these fears seem unfounded as cheek mucosa is now used extensively. The early use of split thickness cheek by Steinhauser (1969) was handicapped in that he could not obtain sufficient tissue with his mucotome. There was concern also that, as cheek mucosa is not highly keratinised, it may not perform well as a denture bearing tissue. Dekker and Tideman (1973) performed histologic studies on free grafts of buccal mucosa and connective tissues after transplantation and reported that the grafts tended to assume the histologic character normally seen over the edentulous alveolar process. The results of vestibuloplasty using full thickness cheek mucosa compared to split

Fig. 20 Lower labial vestibuloplasty with mucosal graft from palate.

thickness mucosa were compared by Maloney et al. (1972) and the latter were found to be superior.

Porcine skin xenographs

Specially prepared frozen sterile pigskin is available commercially and has been used extensively in burn therapy (German et al., 1972 and Wood and Hale, 1972). Sanders et al. (1978) experimenting with dogs, suggested that porcine skin kept wounds of the mouth clean, reduced scarring and contraction, and prevented granulation and hyperplastic tissue formation. Subsequent human trials have verified these findings. Frozen porcine skin is stored in a sterile container at -18°C for up to 18 months. When required it is thawed by immersing in saline solution and the thawed material can be successfully stored at 5°C for up to 14 days.

Because of the relatively small amount of material required for dental procedures porcine skin xenografts are not commonly used. There are occasions however when, because of the patient's medical condition or difficulties associated with the preferred donor site, porcine skin may be considered as a useful alternative.

MYLOHYOID RIDGE SURGERY

In recent times there have been very few publications relating specifically to the surgical smoothing of prominent mylohyoid ridges in the edentulous mandible.

Brown (1953) described his method of dealing with "the flat lower" and suggested that, in the 60 cases treated by him, three features were commonly encountered either singly or in combination:

1. Extensive atrophy of the alveolar ridge.
2. Irregular resorption of the alveolar bone.
3. The presence of a sharp prominent mylohyoid ridge.

The procedure outlined by Brown was accomplished with the patient under general anaesthetic and had as its objective:

1. Detachment of the mylohyoid muscle.
2. Removal of the prominent mylohyoid ridge.
3. Removal of all other irregularities along the edentulous ridge.

To this end incisions were extended on each side of the mandible from the ascending ramus, posterior to the retromolar fossa. These continued downward and inwards to the centre of the ridge and continued to the midline. The lingual mucoperiosteal flap was carefully elevated away from the bone along the extent of the flap, care being taken to protect the lingual nerve. After smoothing the exposed mylohyoid ridge with a surgical bur the flaps were trimmed and sutured. No effort was made to cut the muscle or re-attach it to the bone following smoothing. Brown asserted, "The muscle will later re-attach itself at a much lower level, thus providing a deeper lingual space." Because fascial planes were violated, Brown suggested that the procedure should be managed under prophylactic antibiotic cover.

A few months later, Downton (1954) suggested a different approach "now being used with success at the Postgraduate Institute of Dental Surgery". The flap design advocated by Downton was elaborated to ensure protection of the lingual nerve and closure post-operatively away from the excised mylohyoid muscle. The flap was painstakingly dissected from the muscle surface after which the ridge, together with attached muscle, was separated from the mandible using a chisel. The fragments of ridge were then located in the depth of the wound, drawn up using artery forceps and severed, together with half an inch of muscle. This procedure was claimed to discourage reattachment of the muscle.

As Downton states when referring to the effect of ridge smoothing on the lingual extension of the lower denture, "It must be remembered that the mylohyoid muscle, which is the muscular diaphragm of the floor of the mouth, is attached to the ridge. Therefore, mere filing of this ridge will not allow an increase in depth of the lingual flange. Even if the muscle is detached at the time of smoothing the ridge, reattachment will occur".

It is clear from Downton's comments that although he respected the lingual nerve and advocated a flap design specifically shaped to avoid this important structure, he paid little attention to the variations of anatomy encountered in this region. In addition, by exposing the bulk of the superficial portion of the submandibular gland to the oral cavity, protected only by a thin closing flap of mucous membrane, and by deliberately sacrificing a considerable portion of the "muscular diaphragm of the mouth", he was at risk of causing other complications.

Daniel E. Waite in his Textbook of Practical Oral Surgery (1978) devotes a chapter specifically to pre-prosthetic surgery. He apportions one paragraph to the mylohyoid ridge in which he suggests that "the tissues must be handled with delicacy", after reflecting a mucoperiosteal flap with a horizontal incision on the crest of the ridge. He continues, "when the muscle fibres come into view, they can be sectioned with the scissors or stripped with the periosteal elevator. The bony prominence is then reduced by means of the chisel or the file until the sharpness and/or undercut is removed" (Fig. 21a). He makes no mention of the lingual nerve or the likelihood of the muscle re-attaching later on. His next short paragraph however is much more interesting as it refers to the "endoalveolar crest". The following is a verbatim quote of this paragraph in Waite's book.

"The term 'endoalveolar crest' is not often used, but refers to the bony prominence lingual to the mandibular third molar. This bony balcony is not the same as the mylohyoid ridge. There is no muscle attachment to it, and it should be reduced at the time of third molar removal. When this is not done, the bony projection may become sharp and irritate the tongue, as well as interfere with the prosthesis (Fig. 21b)." Waite concludes the chapter with a few remarks relating to other troublesome prominences of the mandible.

The majority of texts dealing with oral surgery, whether they relate in general, or are specifically written about preprosthetic surgery, refer to mylohyoid smoothing. For example, Kruger (1968) in his Textbook of Oral Surgery, refers to the subject in a section entitled Deepening the Lingual Sulcus - Supraperiosteal method. He advocates incising the muscle, smoothing the mylohyoid ridge and relocating the muscle further down by anchoring it, with sutures passing through the floor of the mouth, attached to skin buttons beneath the chin.

Lawson (1972) wrote of the objectives of pre-prosthetic surgery and paid particular attention to the prosthetic principles which must be followed to construct a successful denture. He then drew attention to troublesome areas of the changed bony anatomy which required surgical alteration.

Finally, Roberts (1977) reviewed the scant literature at the time of his writing on the subject and highlighted the common faults he found in 50 patients examined and treated over a four year period. He emphasized the required features of a satisfactory prosthesis, described the surgery he performed under local anaesthesia and outlined the prosthetic procedures to be followed after completion of surgery. Roberts describes his preferred surgical technique in some detail but his diagrams are confusing. He makes two points however which are interesting. Firstly, his incision commences in the centre of the residual ridge "just anterior to the retromolar pad. Moving laterally and forward, the line of cut describes a slight convexity outward and regains the crest of the alveolar ridge in the premolar region". Secondly, he suggests that the lingual nerve lies in close proximity to the mandible in the third molar region, "therefore it is best to identify this structure and protect it with a suitable retractor during flap reflection". He makes no attempt to resect the mylohyoid muscle and shows a diagram suggesting how the

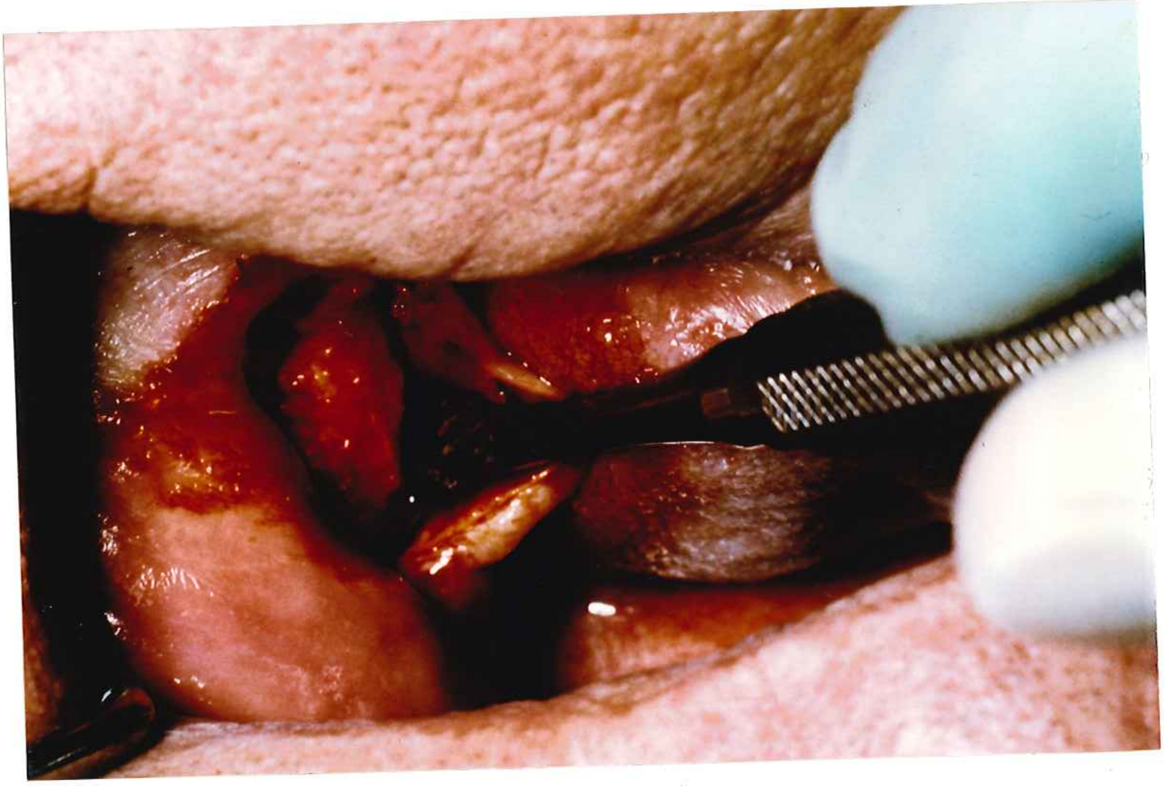


Fig. 21a. Endoalveolar crest exposed for surgical smoothing.

Fig. 21b. Typical ulceration caused by lower denture when crest has not been smoothed.

muscle becomes re-attached lower down, after surgery. However, he does not make clear what steps should be made, if any, to ensure that this occurs.

In his description of the prosthetic technique to be followed after surgery, Roberts acknowledges an important point. That is, that the impression of the lower lingual flange "should reproduce the characteristic "S" shape, elongated anteroposteriorly and flattened in the centre". In this way the prosthodontist can correctly and accurately "read" the impression and know whether the various structures which define the characteristics of a correctly formed impression are in the desired relationship, one to the other. When the mylohyoid muscle is deliberately cut and allowed to contract beneath the tongue, the resultant impression takes on an unfamiliar shape which varies from patient to patient, and it is then difficult to confidently know whether the resulting denture base will be acceptable during normal function.

Author's preferred method of mylohyoid ridge surgery

Once it is decided that elimination of a sharp prominent mylohyoid ridge will benefit the patient, routine precautions are taken to eliminate any complications. For example, the medical history may reveal abnormalities which may contraindicate surgical intervention. Similarly, prescribed medicines should be identified and in collaboration with the prescribing physician they may be changed, modified or withdrawn.

Patients who are apprehensive are prescribed Valium (diazepam), 5-10 mg taken the night before surgery and 5-10 mg taken one hour prior to surgery. The dosage is dependent on body weight.

Proper precautions to ensure sterility are enforced.

It is preferable to perform surgery on one side only. The operation to the other side is performed no less than two weeks afterwards. Frequently patients require simple modification of maxillary tuberosities as well. In this case mylohyoid smoothing and tuberosity modification are performed at the one appointment, the tuberosity surgery following that of the mylohyoid ridge.

Analgesia is effected by a mandibular (inferior alveolar) block injection. This is followed some minutes later with infiltration of the long buccal nerve. It is neither necessary, nor desirable, to infiltrate anaesthetic solution directly into the tissues in the retromylohyoid area.

The incision is made in two distinct directions (Fig. 22). Bone is palpated beneath the retromolar pad and the first incision commences in the centre of the pad by directing the No. 15 blade to cut hard onto the bone (beneath the pad) and moving downward and outward towards the external oblique ridge. The first incision ceases halfway between the residual alveolar ridge and the external oblique ridge and makes an angle to the alveolar ridge of roughly 45°. From this point the incision is continued parallel to the alveolar ridge and then curved gently inwards to reach ridge centre before the mental foramen is reached. Trauma to structures in and around the mental foramen is thus avoided (Fig. 23).

Occasionally it is necessary to extend this part of the incision further in which case care is taken to remain lingual to the mental foramen. The distinct angle made by the two directions of cut of the incision should constitute an easily recognised landmark when bone smoothing is complete.

Commencing at this angle a small periosteal elevator is used to lift the mucoperiosteum buccally along the incision to a depth of 3 mm to facilitate suturing later on. The elevator tip is then faced toward the pharynx and the surgical flap is raised by keeping the elevator hard against bone at all times, moving with the blade parallel to the alveolar ridge, and gradually peeling away the bone by changing the orientation of the instrument as the mylohyoid ridge is reached (Fig. 24). In other words, as the bone profile changes from horizontal to vertical and then back towards horizontal as the undersurface of the mylohyoid ridge is outlined, so does the blade of the

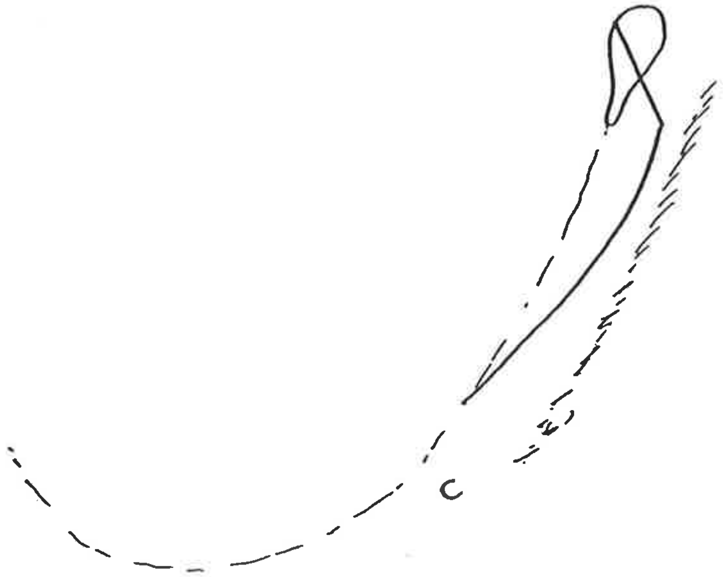


Fig. 22. The first incision across the retromolar pad is angled forwards to a point midway between the external oblique ridge and the alveolar ridge. The second incision passes forwards and gradually curves back to a point on the centre of the alveolar ridge. This ensures wide access to the mylohyoid ridge and results in scar tissue being located away from the alveolar ridge and the elastic vestibular tissue in the buccal sulcus.

Fig. 23. Completed incision terminating near ridge centre.

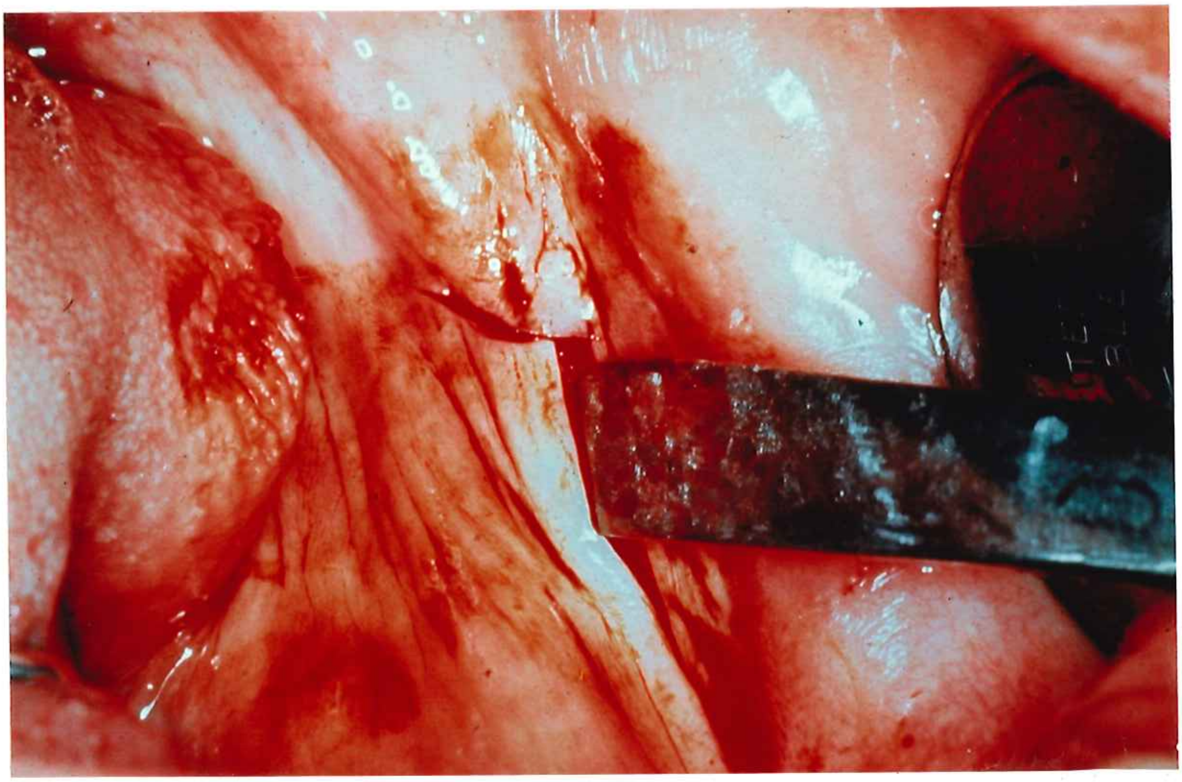


Fig. 24. The periosteal elevator follows the ridge contour.

elevator change its spatial orientation, its long axis rotating more than 90°. In this way the bone is peeled bare of periosteum together with the muscle and its continuum of epimysium. Similarly as the end of the elevator remains hard on bone, the lingual nerve always remains separated from the bone by the elevator and is thus well protected. No attempt is made to disturb the tissues to identify the nerve. Often it is seen lying on the surface of the mylohyoid muscle in close association with the retromolar pad. However its appearance and position vary from person to person.

The flap should now form a triangle with its elongated base parallel to the mandibular body.

The broad-bladed periosteal elevator is then slipped down the mandibular body with its tip firmly on bone to lie almost horizontally. The handle of the elevator depresses the flap and the tongue, lying across the floor of the mouth in the region of the first molar on the side opposite to the operation.

When operating on the patient's left, a right-handed operator holds the retractor with the left hand whilst operating the handpiece with the right hand. The assistant retracts the left cheek with the right hand and operates the high-volume sucker with the left. When operating on the patient's right side, the assistant guides the retractor with the right hand and the sucker with the left. The operator retracts the right cheek with the left hand.

During bone smoothing, which is done with a revolving file, the retractor keeps pace with the file so that at all times there is a protective metal barrier beneath the ridge being smoothed and the rotary instrument can contact bone or metal only (Fig. 25).

The file is kept moving along the ridge to avoid undue heating of the bone as a saline drip is not used. Similarly sucking is kept to a minimum. It is believed that the bone dust, which is created by the file, mingles with blood and forms a useful slurry which is allowed to remain in the wound.

The flap is returned to its original position and the operated area is palpated with the finger (Fig. 26). It is not necessary to continue bone moothing to a marble finish. The combined effect of disruption of the periosteum and deposition of the bone slurry provokes in the first instance bone resorption and in the second the formation of a pad of blood clot dispersed with bone particles. When the flap is closed, the "clot" organises and it is found that, by about ten days, the smoothed ridge is covered by a firm pad of organised healing tissues, presumably composed largely of fibrous tissue.

When it is judged that sufficient smoothing has taken place, the flap is returned and the base is "milked" from under the chin near the submandibular gland. This ensures that excess blood and debris is expelled. There is no necessity to irrigate the site (Fig. 27).

The first closing suture passes through the angle of the first incision bringing the angles to close apposition. A second suture is usually required about one centimetre further forward. The final number of sutures is dependent on flap length but seldom exceeds two. After suturing it will be noticed that the lingual sulcus is slightly wrinkled. This is due partly to the removal of bone but is due also to the fact that tissues, previously bound to bone, are now free (Fig. 28).

Instructions in oral hygiene and management are given to the patient. The lower denture is left out until suture removal seven days post-operatively. At this stage an existing denture can be modified with suitable resilient material, to encourage tissues to adapt to the now accessible posterior lingual sulcus. The opposite side is operated upon two weeks later. Construction of new dentures is not commenced until 28 days after the final surgery.

Provided this procedure is carried out swiftly and with precision there should be no untoward complications.

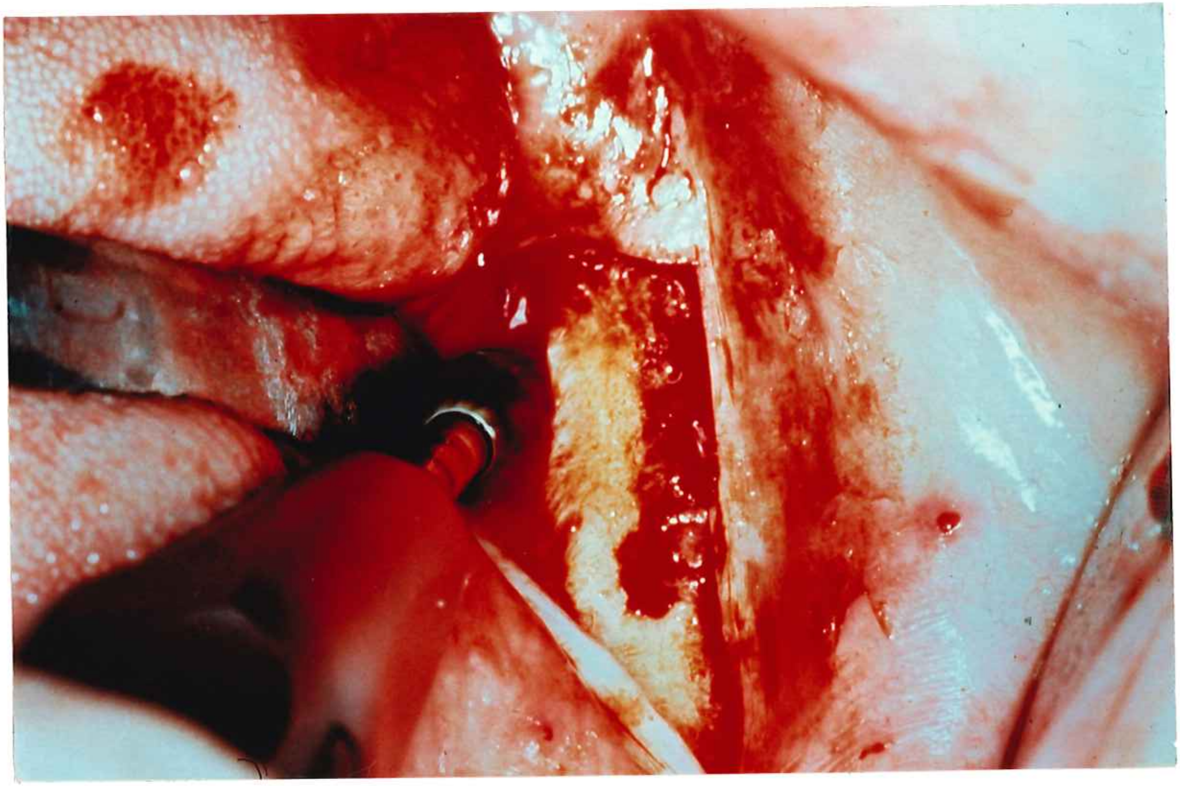


Fig. 25. The elevator protects the lingual nerve by lying at all times beneath the revolving file.

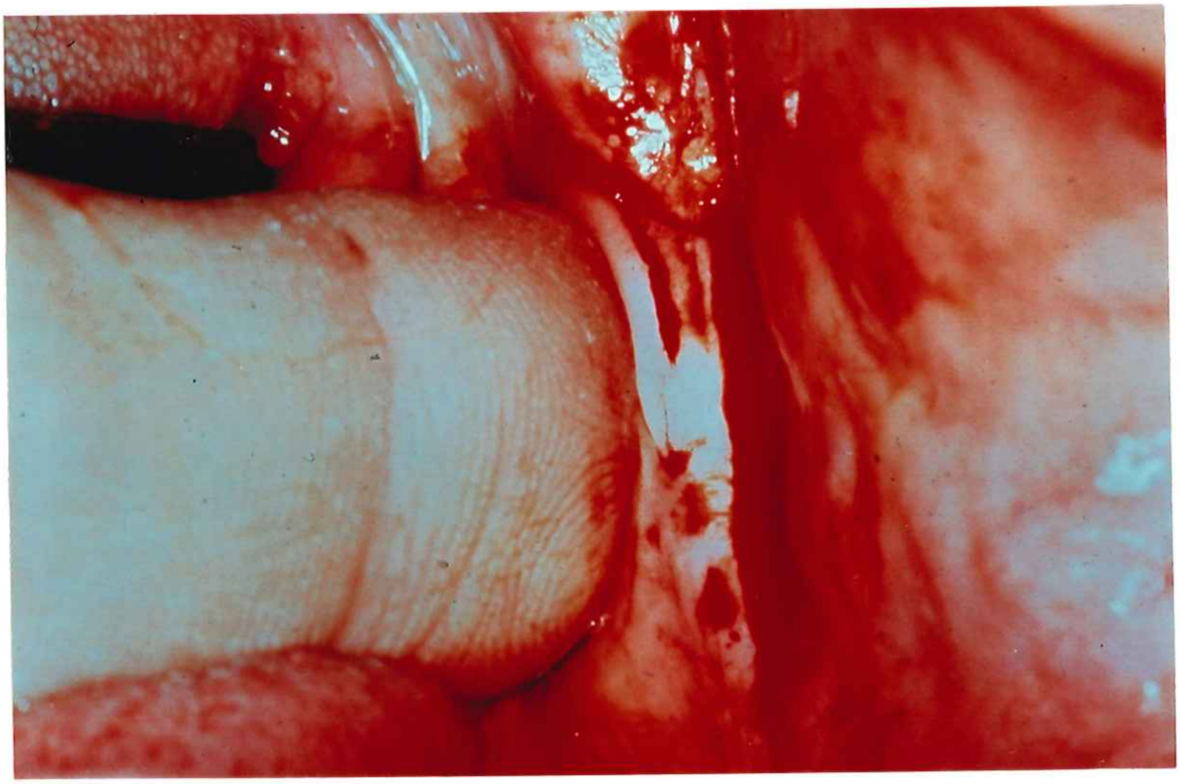


Fig. 26. The smoothed bone being palpated with flap replaced.

Fig. 27. Appearance of flap after "milking".

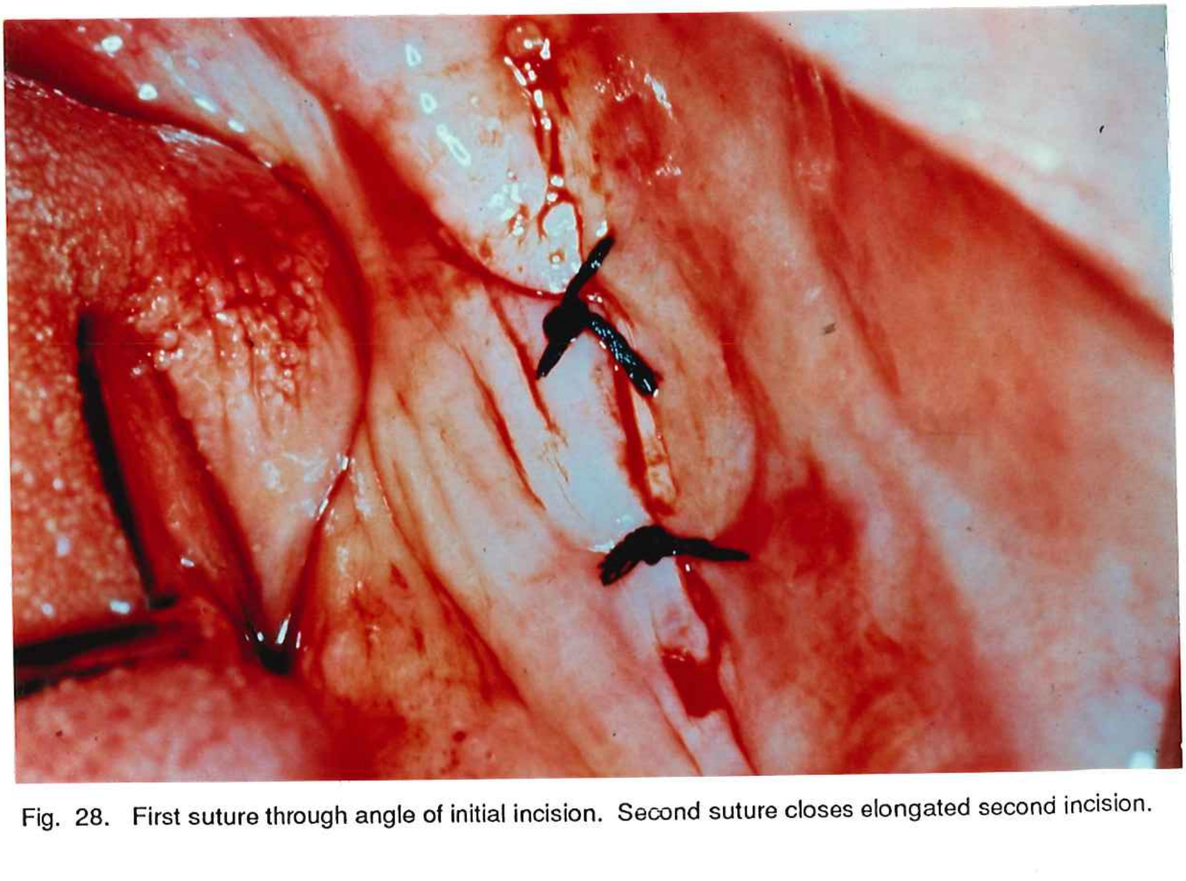


Fig. 28. First suture through angle of initial incision. Second suture closes elongated second incision.

There is no doubt that by deliberately not cutting the mylohyoid muscle in this particular technique, the muscle re-attaches later, but further down the body of the mandible. In the author's experience a distinct mylohyoid ridge can be felt in some cases two to three years later. Occasionally it has been noted that where surgery was completed eight to ten years previously, the ridge appears particularly prominent and quite sharp. It is not possible to predict which cases will again prove troublesome.

By cutting the muscle, as advocated in some of the other techniques (e.g. Downton's), further attachment, and hence ridge formation, may well be avoided. However this procedure is more traumatic and post-operative pain, swelling and bruising can be severe. Similarly the procedure demonstrates little regard for an apparently important structure. On the other hand the author's preferred approach causes little discomfort, allows continued normal function of the oral diaphragm, but may have to be repeated after some years.

SECTION THREE

CLINICAL ASSESSMENT OF THE INFLUENCE OF THE MYLOHYOID RIDGE ON DENTURE COMFORT

INTRODUCTION

An oral prosthesis of any kind is a poor substitute for teeth. No matter how much attention is paid to detail, the wearer of a prosthesis usually experiences bouts of discomfort at some time or another. Patients vary in their response to treatment. However, pain is a subjective phenomenon, whether as a result of an external irritant or from any noxious stimulus. The results of pain are difficult to evaluate in the absence of standardised methods of assessment and measurement. For example, a stimulus which appears to cause pain to one subject may elicit only mild discomfort in another. There is no doubt in the author's mind that in the past, dentists have encouraged patients to tolerate denture-induced pain and soreness by instructing them to persevere, no matter what the underlying cause of their difficulties might be. Apart the from technical obstacles, other factors which are difficult to evaluate may influence the outcome of the most fastidious treatment.

For many reasons elderly people, in particular, experience difficulty in wearing dentures. Loss of elastic fibres with ageing diminishes the quality of the soft tissues that cover the bony ridges. Xerostomia, which can have detrimental effects on healing and comfort, may also be present. Lack of neuromuscular coordination may be an added problem.

The resorption of bone can leave little alveolar ridge for support; prominent muscle attachment sites, such as the mylohyoid ridges or genial tubercles can become painful as dentures impinge on them during chewing. Often exostoses equire special management if prosthetic treatment is to be successful. Many approaches may be tried, the most conservative treatment being the incorporation of a resilient lining on the tissue bearing surface of the prosthesis.

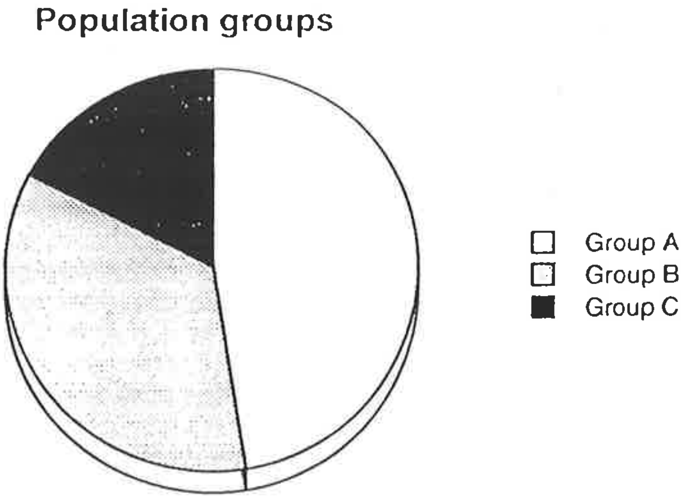
Surgeons have advocated many methods of modifying edentulous ridges, prior to the making of dentures. These methods have been reviewed earlier in the previous section. Some of the procedures, such as visor osteotomy, can be quite debilitating for the patient; they may also present prosthodontic difficulties.

The simple smoothing of the mylohyoid ridge is an operation easily performed under local anaesthesia and it is generally well tolerated by the elderly patient. The procedure was described by Brown (1953) and Downton (1954), but more recently it has been modified (Fitzpatrick, 1978) so that there is no longer the need to cut through the mylohyoid muscle. Instead, the muscle is peeled down and away from the ridge whilst remaining attached to the periosteum. (See Section 2 for more detail.)

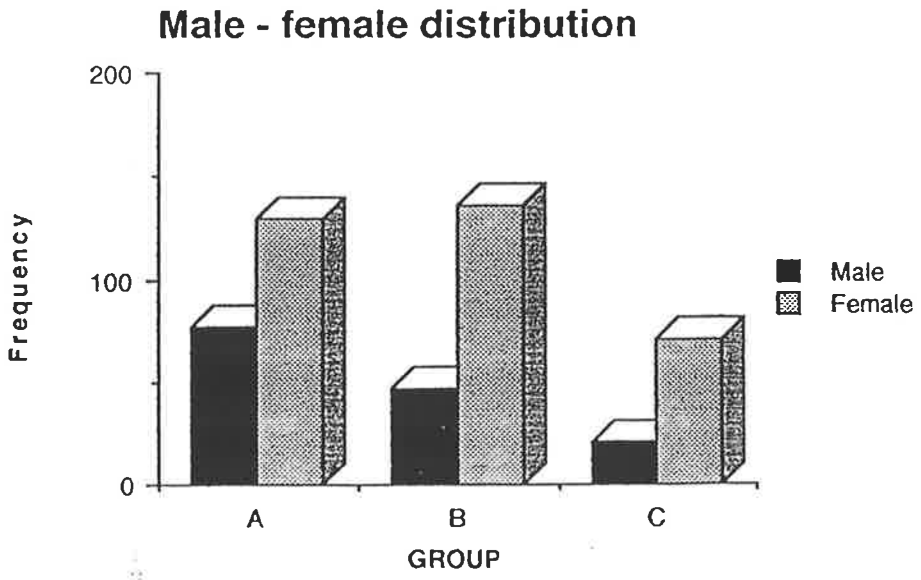
Little statistical documentation of the outcome of this care is available, although Roberts (1977) did report a preliminary evaluation based on the results of the treatment of 36 patients. Nineteen patients had surgical treatment of mylohyoid ridges prior to prosthetic care, whereas the remaining 17 did not. Results indicated that 16 of the 19 patients who underwent surgery (84.1%) remained comfortable with their new dentures, for a period of 5 years, whereas only 4 patients out of the remaining 17 patients (23.5%) were comfortable during the 5 year period. To Roberts, this suggested a marked benefit had been derived from the surgical treatment over a period of 5 years.

TREATMENT GROUPS

In the present study the clinical records of a group of 521 patients, treated in the author's specialist clinical practice, were reviewed (Fig. 29). The purpose was to evaluate the outcome of the surgical smoothing of the mylohyoid ridge prior to making complete dentures for a large group of patients over a wide age range, outside an institutionalised setting. Many of the variables which are endemic to most large clinical studies were reduced, in that as far as possible, all procedures including laboratory work were



Group A = 247 (77 males, 170 females)
Group B = 183 (47 males, 136 females)
Group C = 91 (21 males, 70 females)



Figs. 29. The distribution of the main study groups.

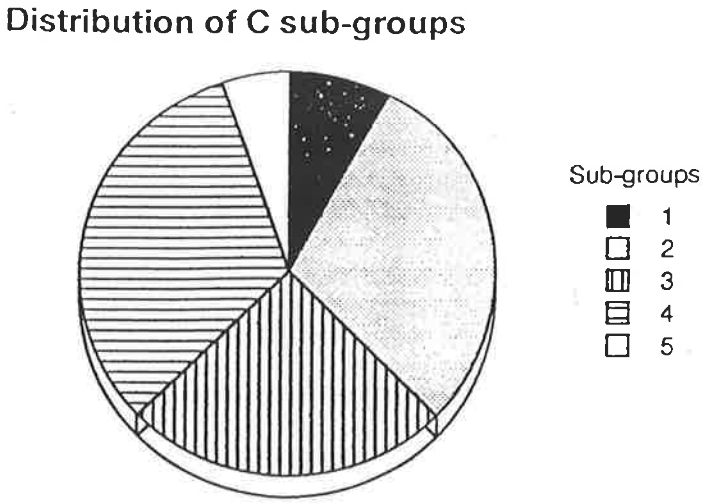
carried out by the author. The subjects were categorized into three groups, denoted A,B and C. Group C was further sub-divided into five sub-groups.

A total of 521 patients (145 males and 376 females) were included in the study, all of whom subsequently received new full dentures. Of the total, 247 (Group A) patients were not considered to have potentially troublesome mylohyoid ridges, therefore no surgery was advised. The remaining 274 patients demonstrated sharp ridges that required simple surgical smoothing prior to denture construction, in order to avoid future discomfort from a lower denture. Of this remaining 274 patients, 183 patients (Group B) had surgical correction and 91 patients (Group C) did not (Fig. 29). The Group C patients (21 males and 70 females) did not proceed with surgery for a variety of reasons and were divided into five sub-groups, which, though the numbers were too small for detailed statistical analysis, provided some interesting and pertinent observations regarding the management of the edentulous patient.

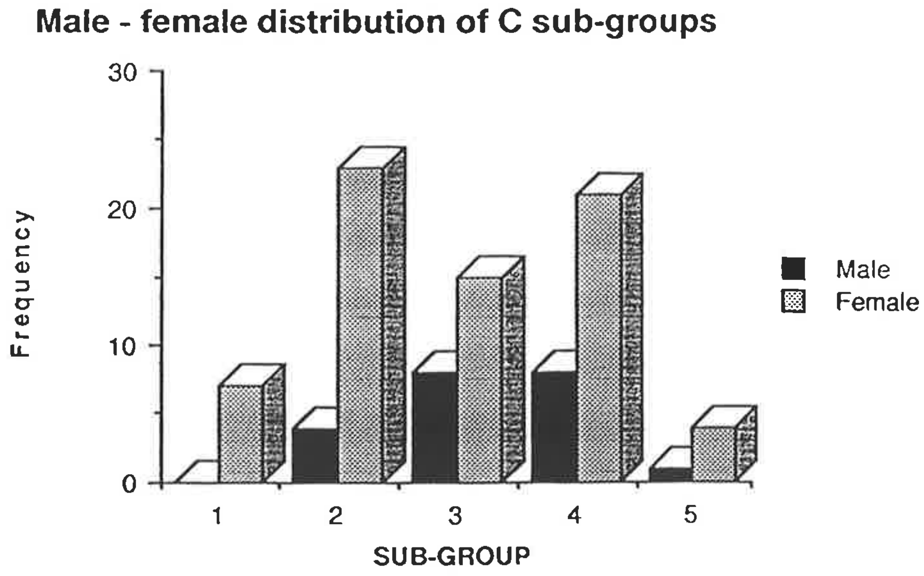
Sub-groups of Group C (Fig. 30)

Sub-group 1. This sub-Group Comprised 7 females who had already been subjected to major pre-prosthetic surgery to alleviate discomfort from a prosthesis, e.g. absolute augmentation of the mandible following a visor-split with bone grafted from hip, ribs, etc., and supplemented with skin or mucosal grafting from palate, cheek, leg or arm. In all of these patients there remained prominent and sharp mylohyoid ridges and many had enlarged tuberosities. In the author's opinion, these factors precluded comfort from future denture wearing, but the patients steadfastly refused further surgery.

Sub-group 2. This Group Consisted of 4 males and 23 females who had obvious "psychological" problems and displayed a distinct surgery phobia. All recounted frightening experiences in their youth, related to dental



Subgroup 1 = 7 (0 males, 7 females)
Subgroup 2 = 27 (4 males, 23 females)
Subgroup 3 = 23 (8 males, 15 females)
Subgroup 4 = 29 (8 males, 21 females)
Subgroup 5 = 5 (1 male, 4 females)



Figs. 30. The distribution of C-subgroups. (see Table II, page 100)

surgery. In addition they described bizarre symptoms, without demonstrating any clear signs of them.

Sub-group 3. These patients (8 males and 15 females) had complex medical histories, e.g. of abnormal bleeding, cardiac disease, a complex drug regime, etc.

Sub-group 4. These patients (8 males and 21 females), in addition to being averse to further surgery, appeared to demonstrate a very high pain and tolerance threshold. In each case there was poor bony and soft tissue configuration, together with very poorly-constructed and inefficient dentures, which (under normal circumstances) should have caused gross discomfort. The only complaint was related to the age of the dentures or their lack of aesthetic appeal. These patients were easily pleased and it was not possible to convince them of the advantages of minor pre-prosthetic surgery.

Sub-group 5. There were 5 patients (1 male and 4 females) in this category. All had suffered such severe bone loss in the lower jaw that too little tissue remained upon which to carry out surgery without causing complex side effects. In some cases only 3mm. of bone height remained. Any attempt to "split" the remaining bone and augment the two halves would probably have failed. The mandibles of these patients appeared to consist of a thin, concave ribbon of bone bounded by the mylohyoid and external oblique ridges.

ANALYSIS OF DATA

To determine whether there was a significant relationship in the performance of patients between the three main treatment groups data were analysed statistically by chi-squared analysis. The probability level for statistical significance was set at 5%. Patients were grouped into three age categories: those who were less than 50 years old; those between 50-59 years of age, and those 60 years or older. Performance of the patients was based on the number of post-insertion visits required: less than three, or three or more. Most patients generally manage their complete dentures without major difficulty after one or two post-insertion visits. Therefore the need for three or more visits was used in this study as a crude index of a less satisfactory outcome of treatment.

Comparisons were made initially between the three treatment groups using data pooled for sex and age, then for data from males and females separately. Comparisons were then made between the three groups for each of the age categories, first for both sexes combined then for males and females separately. After making comparisons between the different treatment groups, comparisons were made within each group taking into account age and gender.

It was hypothesised that Group A, i.e. those patients whose mylohyoid ridges did not appear to constitute potential discomfort, would probably require fewer post-insertion visits than the other two groups, and that Group C would probably require the greatest number of post-insertion visits. That is, it was hypothesised that Group A would perform best, Group B less so, and Group C not as well as either of the other two groups.

RESULTS AND DISCUSSION

Table 1 gives results of the clinical study.

Between groups

Interestingly, the results showed that Group B patients (those subjected to pre-prosthetic surgery) performed better than expected. Only 13 (7.1%) of the 183 in this group needed three or more post-insertion visits, whereas in Group A, out of a total of 247 patients, 42 (17%) required three or more post-insertion visits. Group C, as predicted, did not respond as well, in that, out of a total of 91 patients, 23 (25.3%) required three or more post-insertion visits for adjustment before they were comfortable. The association between treatment groups and number of post-insertion visits for all patients was found to be statistically significant (χ^2 = 17.29, 2 degrees of freedom, p = .001.

Data for males and females were then analysed separately. The association between number of post-insertion visits and treatment groups was not significant at the 5% level when males only were considered (χ^2 = 4.07, 2 degrees of freedom, p = 0.13) but the sample size was small. The males did, however, show a similar trend to the total sample, with only 6 of Group B males (12.8%) requiring three or more post-insertion visits compared to 14 (18.2%) of Group A males and 7 (33.3%) of Group C males. When females were assessed separately, the association between number of post-insertion visits and treatment groups was found to be statistically significant (χ^2 = 14.60, 2 degrees of freedom, p = .001).

Comparisons between the three treatment groups were then made based on each of the age categories, firstly for males and females combined then for both sexes separately. There was some evidence of differences in performance between the study groups related to age, however the only significant association between number of visits and age was noted in the 60+ age group where only 4 of Group B patients (5.26%) required three or

Table 1

RESULTS OF CLINICAL STUDY

	GROUP A			GROUP B			GROUP C		
	<3 Visits	3+ Visits	Totals	<3 Visits	3+ Visits	Totals	<3 Visits	3+ Visits	Totals
Age Years	% No.	% No.		% No.	% No.		% No.	% No.	
MALE									
<50	92.9 (13)	7.1 (1)	100.0 (14)	100.0 (9)	0 0 (0)	100.0 (9)	0.0 (0)	100.0 (1)	100.0 (1)
50-59	91.3 (21)	8.7 (2)	100.0 (23)	71.4 (10)	28.6 (4)	100.0 (14)	75.0 (6)	25.0 (2)	100.0 (8)
60+	72.5 (29)	27.5 (11)	100.0 (40)	91.7 (22)	8.3 (2)	100.0 (24)	66.7 (8)	33.3 (4)	100.0 (12)
FEMALE									
<50	82.5 (33)	17.5 (7)	100.0 (40)	94.3 (33)	5.7 (2)	100.0 (35)	100.0 (11)	0.0 (0)	100.0 (11)
50-59	77.4 (24)	22.6 (7)	100.0 (31)	93.9 (46)	6.1 (3)	100.0 (49)	76.5 (13)	23.5 (4)	100.0 (17)
60+	85.9 (85)	14.1 (14)	100.0 (99)	96.2 (50)	3.8 (2)	100.0 (52)	71.4 (30)	28.6 (12)	100.0 (42)
TOTAL	82.9(205)	17.1 (42)	100.0(247)	92.9(170)	7.1 (13)	100.0(183)	74.7 (68)	25.3 (23)	100.0 (91)

more post-insertion visits (χ^2 = 13.78, 2 degrees of freedom, p =.001). Patients aged less than 50 years showed a similar trend in that only 4.5% of Group B required three or more visits, whereas 14.8% of Group A and 8.3% of Group C fell into that category. Patients in the 50-59 years age Group Also demonstrated a similar but non-significant trend.

When comparisons were made between groups in each age category for males and females separately, there were no significant associations from the chi-squared analyses. However, the numbers were small, particularly for males. Despite this, the males in the 60+ age group displayed a result approaching significance, in that 8.3% of Group B males required three or more post-insertion visits compared with 27.5% of Group A males and 33.3% of Group C males. Females performed similarly to the males in that there was a trend for those in Group B to perform better, with the 60+ age group demonstrating a significant relationship with treatment group (χ^2 = 11.47, 2 degrees of freedom, p = .001)

There was one notable exception against the trend in females under 50 years, in that none of the Group C patients returned more than twice for post-insertion adjustments. As the numbers involved (11) were small, no statistical analyses were performed. However, this result supports the strong impression that females under the age of 50 years showed very high tolerance thresholds. Despite this, it should be noted that Group C patients had sound reasons for not opting for pre-prosthetic surgery, including the major fact that many of them had already undergone serious surgery of some kind and were anxious to complete their treatment without further complication. Patients were all encouraged to return for adjustment if in pain, but it is possible that the lack of further visits may have arisen from a fear that prolonged treatment might indicate the necessity for further surgical intervention.

Within groups

Apart from comparisons between treatment groups, relationships were also analysed within the different study groups, with associations between age and number of post-insertion visits and between gender and number of visits being considered. No significant associations between gender, age based on three categories, and number of post-insertion visits were noted.

Data for the two age categories under 60 years were then combined, enabling performance by patients under 60 years and those over 60 years of age to be assessed. No significant associations between age (based on these two categories) and number of post-insertion visits were noted within any of the treatment groups when data for both sexes were considered together. However, separate analyses of data for males and females yielded one significant result, with Group A males under 60 years of age performing better than those over sixty years ($\chi^2 = 4.86$, 1 degree of freedom, $p = .026$). That the under-60 year old group of males should perform better than the older males or females may be a reflection of their occupations. Each of these patients had high profile occupations or very responsible positions. The inference is drawn that they were fully occupied and had little or no time to reflect on personal problems. Indeed it was often difficult to arrange their treatment visits to suit very busy work schedules.

The older males had less frantic lifestyles, and for the most part were retired, semi-retired or nearing retirement age. It was noticeable that many older males considered that provision of dentures in their mid-60s, or later, constituted the last dental treatment that they were likely to receive. They tended to be more demanding and pernickety than their younger counterparts which leads the author to suspect that these two factors are related.

It was of interest to consider whether any significant association existed between gender and the number of post-insertion visits within each treatment group (A/B/C) for each age category. In the under-50 year age category in Group A there was no significant statistical association between gender and treatment outcome, though there was some indication that males in this category performed better than females. 17.5% of the females under 50 years required three or more visits, whereas only 7.1% of the males returned 3 or more times. The numbers in groups B and C were small and no attempt was made to analyse the data in these categories in detail.

In the 50-59 year category in Group A, there was no statistically significant relationship between gender and number of post-insertion visits, but there was the suggestion that males performed better, in that only 2 out of 23 (8.7%) males required three or more visits compared with 7 out of 31 (22.6%) females.

The comparison in Group B patients showed a reverse of this trend, with females demonstrating a significantly better outcome than their male counterparts. Of the 14 males, 4 (28.6%) required three or more visits, whereas 3 of the 49 females (6.1%) required three or more (χ^2 = 5.56, 1 degree of freedom, p = .176).

There was no significant relationship between males and females amongst the Group C patients of this age, in that 25% of male patients and 23.5% of female patients needed to attend on more than two occasions after insertion of their prostheses.

In comparing males to females in the 60+ age category, there was no significant difference in either of the three treatment groups. In Group A however, females appeared to perform better than males; 27.5% of males (11 of 40) compared to 14.1% females (14 of 99), required three or more post-insertion visits (χ^2 = 3.45, 1 degree of freedom, p = .06). In this age group, Group B males and females performed well, only 2 out of 24 males and 2 out of 52 females requiring three or more visits for completion of treatment.

In Group C, males and females showed differences in respect to their results, 33.3% of males (4 of 12) and 28.6% of females (12 of 42) requiring more than two post-insertion visits. This result was similar to that of the younger Group C patients (50-59 years) and, although none of this group was expected to perform well, it is worth noting that as age increased, their performance declined. There were 70 females in Group C and only 21 males, making comparative analysis difficult, e.g., there were 11 females under 50 years but only 1 male. Of the latter age Group All of the females completed their treatment without requiring more than two visits, whereas the only male needed three or more visits before he was free of discomfort.

Group C sub-groups

No statistical analysis of the results of the various sub-groups in Group C was attempted because of the small numbers involved. There were however some interesting trends which can be seen from Table 2.

Table 2.

	Male			Female		
Sub-groups	<3	3+	Total	<3	3+	Total
1	0	0	0	57.1%(4)	42.9%(3)	7
2	50%(2)	50%(2)	4	69.6%(16)	30.4%(7)	23
3	50%(4)	50%(4)	8	80%(12)	20%(3)	15
4	100%(8)	0	8	85.7%(18)	14.3%(3)	21
5	100%(1)	0	1	50%(2)	50%(2)	4
	71.4%(15)	28.6%(6)	21	74.3%(52)	25.7%(18)	70

Sub-group 1.

Prior to referral to the author the patients in this group had not been initially examined by a prosthodontist. They had complained mainly of gross discomfort following construction of new prostheses in a general practice. As none of the usual procedures to alleviate discomfort were successful in the general practice, these patients had been referred on to various oral surgeons for advice on their prosthodontic difficulties.

The solution to their problems focused at that time on the surgical manoeuvres that could be carried out in an attempt to repair and rebuild badly damaged mouths, rather than to find a reason for the continual discomfort from denture wearing. In each case of major surgical intervention, the patient was left with varying degrees of permanent damage. In addition, the resulting discomfort and aesthetic changes were unacceptable to the patient. For example, augmentation can be followed by a permanent parasthesia or anaesthesia of the lower lip, which is most distressing. Similarly, submucous vestibuloplasty in the lower labial sulcus, carried out either as an isolated procedure or secondary to augmentation, can often result in lack of control and drooping of the lower lip, as well as sensory disturbance. Patients in this category were all females and were not expected to do well prosthodontically. The results show however, that only 3 of the 7 females (42.9%) in this sug-group required three or more post-insertion visits, which was better than expected considering their history.

Sub-group 2.

This was one of the larger of the sub-groups and females fared better than the males. Of the 23 females, 16 (69.6%) required two or less post-insertion visits, whereas of the 4 males involved, 2 (50%) were comfortable in two or less visits.

Sub-group 3.

This Group Consisted of 23 patients (8 males and 15 females); 12 of the 15 (80%) females were comfortable in two or less post-insertion visits, whereas 2 of the 4 males (50%), as in sub-group 2, were also comfortable in two or less visits.

Considering that all patients in Group C were seriously incapacitated for one reason or another, they all performed far better than expected. It may be however, that the complex variety of sedatives and tranquillisers commonly taken by all of the group, masked their normal reactions to discomfort from trauma. Had they not been sedated their results may have been less satisfactory.

Sub-group 4.

This was the largest of the sub-groups and the results bear out the prediction that, because they had suffered enormous damage without complaint and appeared to tolerate appalling dentures, they would probably perform well with carefully made prostheses without the recommended surgery.

Of the 21 females, 18 (85.7%) required up to two visits until comfortable, whilst all of the 8 males (100%) required up to two visits. It is always interesting to consider why patients at this extreme end of the spectrum behave as they do. Nothing done by the prosthodontist seemed to cause them dismay or discomfort, whereas some other individuals in the study required only the slightest provocation to cause upset.

Sub-group 5.

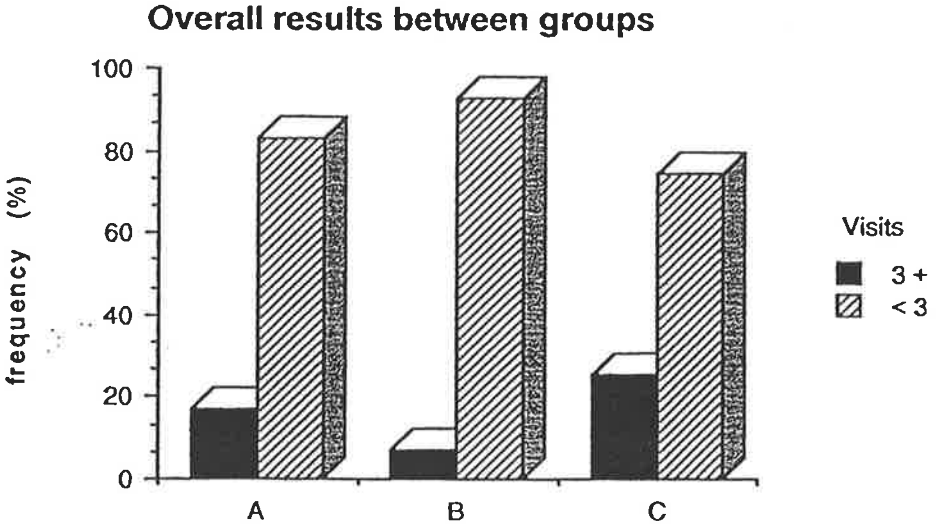
There were no obvious trends demonstrated in the 5 patients of this group; 3 patients (1 male, 2 females) completed their treatment in two or less visits, the remainder (2 females) required three or more visits.

GENERAL DISCUSSION

The results suggest that surgical smoothing of prominent mylohyoid ridges can assist patients to gain a greater measure of comfort with a lower denture in the short term. In fact, the Group B patients required fewer post-insertion visits than those in Group A. This was surprising, but may be explained by the fact that surgery was advocated only when bony prominences were sufficiently pronounced to be considered a potential source of trouble. In addition, many of the patients in Group A presented with badly constructed, under-extended dentures, which was reason enough for providing them with new prostheses. Whilst many in Group A may have had palpable mylohyoid ridges that, at the time of initial consultation, were not thought to pose a potential problem, some proved to be troublesome during treatment.

Considering the groups in total, Group B performed markedly better than Group C (Fig. 31). Some of the Group C sub-groups however recorded success rates very similar to the Group B patients. For example, it was expected that the 29 patients in Group C sub-group 4 would have an excellent prognosis, since they had a history of tolerating dentures under adverse circumstances. Nevertheless, with 3 out of 29 (10.3%) requiring at least three post-insertion visits, they did not perform better than the total of Group B patients (7.2% requiring three or more visits).

The males in Group C performed better than the females in the same group, in that 6 out of 21 (28.6 %) of the males required three or more post-insertion visits, compared with 18 out of 70 of the females (25.7%). It is difficult to account for this apparent disparity, as the only outstanding difference between the groups was the ratio of females to males. Of the females in Group C, 11 were aged 50 years or younger, the total age range being from 30 to 80 years. There was only one male in Group C under the age of 50, their total age range being from 45 to 80 years.



Group A – 17.1% required 3+ visits.
*Group B – 7.1% required 3+ visits.
Group C – 25.3% required 3+ visits.

Fig. 31. Note that Group B have peformed markedly better than predicted.

This small difference in the age range may have influenced the statistical results.

One other point of interest is that out of the total of 521 patients in the study group, no males had a history of major pre-prosthetic surgery, such as absolute augmentation. During the initial consultations with the patients, the impression gained by the author was that the major surgery suggested by some oral surgeons had been offered as a solution to all of the patients' prosthodontic problems including those relating to aesthetics. This emphasises an important principle in patient management, that no irreversible procedure should be prescribed and carried out unless the patient and the operator clearly understand the limitations of the operation.

SECTION FOUR

THE ENDOALVEOLAR CREST

INTRODUCTION

During examination of patients in the treatment groups described in the previous section, it was confirmed that not all of the exostoses which appeared to be the source of discomfort were in fact the mylohyoid ridge. Rather, they represented a small ledge of bone situated above and distal to the mylohyoid muscle attachment.

An extensive review of the literature relating to descriptive anatomy, pre-prosthetic surgery and oral anatomy revealed only three references to this bony exostosis. Daniel E. Waite (1978) in his Textbook of Practical Oral Surgery, describes the feature thus: "The term endoalveolar crest is not often used but refers to the bony prominence lingual to the mandibular third molar. This bony balcony is not the same as the mylohyoid ridge. There is no muscle attachment to it and it should be reduced at the time of third molar removal. When this is not done the bony projection may become sharp and irritate the tongue as well as interfere with the prosthesis".

Volchansky and Makings (1984) published the results of their investigation into 100 South African Negroid skulls from the Raymond Dart collection at the University of the Witwatersrand Medical School. These authors had been searching for the presence of unusual exostoses or tori on the lingual aspect of the mandible. They found a ridge, similar to that described by Waite, in 80 of the 100 mandibles examined. In the discussion of their paper they stated, "In this study it was not possible to relate the presence of the bony ridge to function but it was felt that it may be due to the presence of muscular or ligamentous insertions. ..... The reason for the presence of this bony ridge is still not clear and requires further investigation with particular reference to function and muscle insertions". They had earlier stated that this particular exostosis had not been described in standard anatomical texts nor in any of the papers to which they refer in their publication.

Huelke (1973) refers to the mylopharyngeal line and describes it as the origin of the mylopharyngeus part of the superior constrictor muscle. With reference to the dissection of this area he writes: "Locate the nerve (lingual) below the mylopharyngeus portion of the superior constrictor muscle and medial to the lingual tuberosity of the mandible." Further on he suggests that in the edentulous specimen, changes obviously occur in the relationship between the structures: "Also observe the altered relation of the lingual nerve at the rear of the paralingual space in edentulous cases (molar teeth gone). Would the mylohyoid nerve be involved? Why? In cases of extreme posterior alveolar absorption, what happens to the lingual tuberosity? What happens to the mylopharyngeus part of the superior constrictor muscle and to the attachments of the pterygomandibular raphé?"

The literature review provided few answers to Huelke's queries and confirmed that there is little information on the anatomical variability of structures in the retromolar region, either with respect to changes within an individual related to age and loss of teeth, or between individuals. This has been the experience of the author who, during the examination of many hundreds of patients over a period of 30 years, has noted that the morphology of the posterior part of the edentulous mandible varies markedly between individuals. This variation places them into one of four easily distinguishable categories.

1. Those displaying prominent but well-rounded mylohyoid ridges situated well below the residual ridge crest. This type of ridge is unlikely to cause discomfort in association with a well-extended denture base.
2. A group including patients similar to those in category 1, but in addition displaying a quite separate spine or ridge of bone, namely the endoalveolar crest which is situated distal to and slightly above

the mylohyoid ridge. This is inevitably found to be the source of some discomfort in denture wearers.

3. In this category severe resorption has resulted in a distinct and sharp mylohyoid ridge that requires surgical attention. There is no evidence of a separate endoalveolar crest (Fig. 32).
4. As in category 3, the mylohyoid ridge of patients in this group is prominent and sharp. Resorption is advanced to the stage that the remaining alveolar bone is level with the mylohyoid ridge and the endoalveolar crest, having descended with the alveolar bone, has fused with and become part of the mylohyoid ridge anteriorly and the internal oblique ridge posteriorly. As a consequence it is difficult to define the extent of the surgical smoothing that might be required in cases such as these (Fig. 33).

These distinct differences, particularly in regard to a separate crest, found amongst patients in the clinic setting, stimulated further enquiry. In the first instance all of the available skulls housed in the various teaching clinics of the Department of Dentistry, The University of Adelaide, were examined. In addition, 3 edentulous mandibles from the same source were examined. As the prevalence of crests was found to be high in this collection, and, as only 3 of the mandibles in the Dental School teaching material included edentulous areas, permission was sought to examine a collection of Australian Aboriginal skulls held in the South Australian Museum. Unlike the skulls selected for teaching purposes which had an intact anatomy and were fully dentate, the Australian Aboriginal skulls displayed wide variations of age and condition. Their ages ranged from newborn to mature adulthood. The latter specimens showed varying degrees of edentulousness and in some cases there was severe alveolar bone resorption. It was therefore possible to observe the structure and developmental changes of the alveolar crest from birth to old-age within the collection.

Fig. 32. Sharp mylohyoid ridge which would have required surgery.

Fig. 33. The ridge extends upwards to merge with the temporal crest of the ramus. The three structures have now merged to continue into the ramus.

Permission was also sought to examine part of the collection of primate skulls in the South Australian Museum as it seemed likely that some primates may have a similar configuration to humans in regard to the mylohyoid ridge and the endoalveolar crest.

On preliminary examination of this large sample of human and primate skulls it became clear that the groove produced by the lingual nerve was located between the endoalveolar crest and the mylohyoid ridge, and, that the crest formed a bony protection for the lingual nerve as it emerged from beneath the superior constrictor muscle (Fig. 34). This was particularly interesting to the author as it had previously been suggested that whilst carrying out his preferred method of surgery to smooth the mylohyoid ridge (see Section 3), the first oblique incision made might constitute a danger to the lingual nerve. The author, however, has always maintained that the procedure is safe. Following the examination of the skulls it appeared that the lingual nerve was afforded some bony protection and it was therefore decided to pursue the investigation by carrying out dissections on human cadavers. Both preserved and immediately post-mortem specimens were examined.

The aims of this part of the study were:

1. To establish the frequency of occurrence of the endoalveolar crest as a distinct anatomical feature in a variety of related species.
2. To note the variation of expression between individuals and species.
3. To note the relationship of the crest to the mylohyoid ridge and the closely related soft tissues of the retromolar region of the mandible.
4. To record the changing relationship of the bony ridges and related soft tissues following tooth loss and bone resorption.
5. To consider the function of the endoalveolar crest and to establish whether or not it served both as a bony protection to the lingual nerve and as a significant muscle attachment.

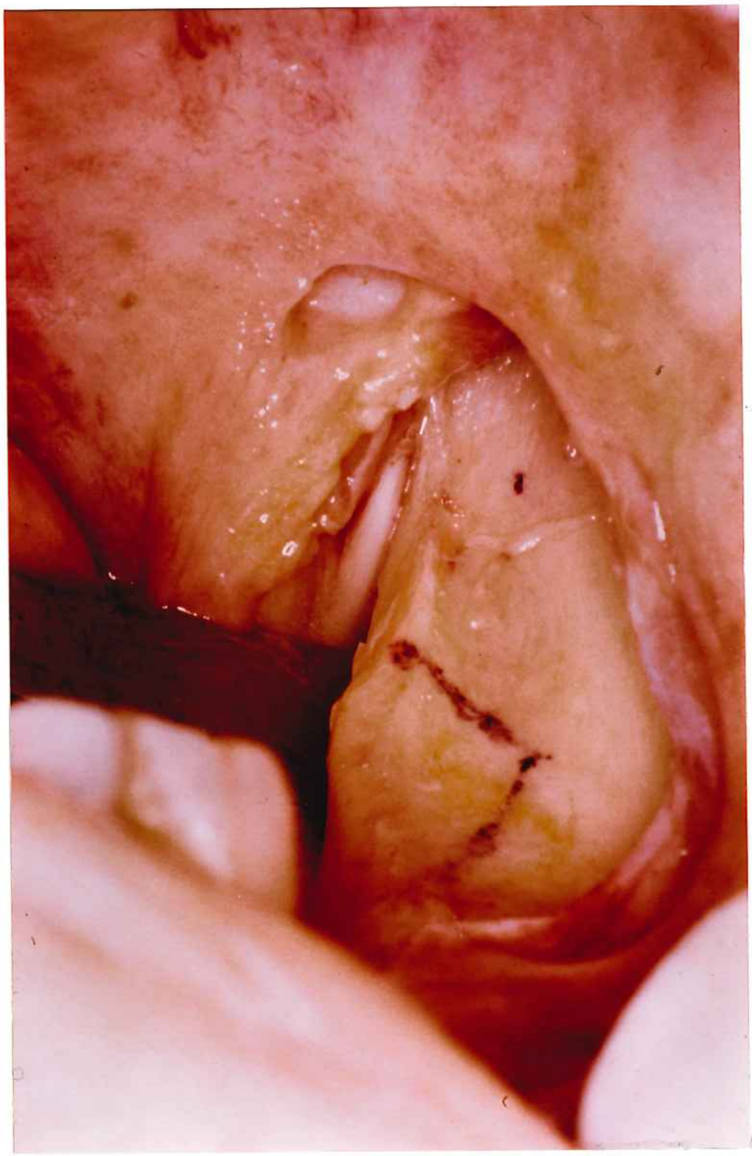


Fig. 34. The tissues distal to the incision (marked on bone) have been displaced distally to display the lingual nerve emerging from beneath the superior constrictor muscle, protected by the periosteal elevator and passing beneath the endoalveolar crest (fresh cadaver).

MATERIALS AND METHODS

Materials

The materials used consisted of skeletal material and cadavers.

1. Caucasian skulls and mandibles (52)
2. Australian Aboriginal mandibles (48)
3. Primate skulls (16)
4. Preserved human cadavers (4)
5. Post-mortem autopsy specimens (5)

Skeletal material

52 intact Caucasian skulls were examined. These were part of the collection of teaching material housed in various parts of the Dental School of the University of Adelaide. They were all presumed to be those of mature adults, since all of the secondary teeth had erupted and were in occlusion. It was not possible or practicable to accurately attribute an age to them. In addition, 3 edentulous Caucasian mandibles, displaying varying degrees of bone loss, were examined.

From the collection of Aboriginal skulls housed in the South Australian Museum, 48 mandibles were examined. This sample of mandibles comprised:

2 neonates
9 adolescents
23 mature adults
14 aged adults - partially or entirely edentulous

The condition of these skeletal remains varied, depending on the soil-type at the original burial site.

The collection of intact primate skulls in the South Australian Museum was also examined. In the case of many of the larger skulls, it was possible to view the mandible separately, but in the case of some of the smaller and more delicate specimens the mandibles were wired in place to the skull to prevent accidental damage. The latter were left wired intact and not recorded in the study.

Preserved human cadavers

Dissections were performed on 4 male cadavers selected from the teaching material in the Department of Anatomy of the University of Adelaide. The specimens were either totally edentulous, or all of their molar teeth were missing from the mandibles.

Post-mortem autopsy specimens

With the permission of Prof. B. Vernon-Roberts, Department of Pathology, it was possible to examine and operate on 5 post-mortem specimens prior to autopsy in the Royal Adelaide Hospital mortuary. This part of the study was difficult to organise because of the logistics involved. It was not possible to carry out the investigation after autopsy, since all of the oro-pharangeal contents are removed and re-arranged during this procedure. These constraints limited the examination to 5 corpses.

Methods

Most of the skulls examined, including all of the Aboriginal mandibles, were photographed. Of the Caucasian skulls in the Dental School collection only those which displayed a particularly interesting characteristic, with regard to the endoalveolar crest or mylohyoid ridge, were photographed. In order to scale the primate mandibles, a millimetre rule was placed alongside each separated specimen, prior to being photographed. In addition, the flash-light source used in making the photographs was positioned to throw the endoalveolar crest into relief.

Each of the cadavers underwent operation as if surgery for mylohyoid surgery was being performed. In the case of the formalin preserved cadavers, the procedure was relatively simple, as was the photography, since in most cases the specimens had been divided through the mid-line in the sagittal plane, offering easy access to the area under study.

The post-mortem specimens were difficult to photograph because rigor mortis made access awkward, thus leaving little choice for positioning of the light source for optimum results.

RESULTS

It was established that the endoalveolar crest was present, prior to severe bone resorption, in all of the human material examined. In addition, the primate mandibles displayed a wide variation in expression of the crest in the sample studied.

Caucasian skulls

All of the mandibles in this group were intact and displayed only minor localised bone loss compatible with varying degrees of periodontal disease. In each case the mylohyoid ridge was easily defined and there was little variation in its expression. In some cases it was expressed as a slightly raised ridge arising below the lingual nerve groove and passing obliquely downward and forward to blend with the lingual plate of the mandible in the region of the canine root tip. In most cases it remained boldly defined to reach the region of the genial tubercles.

The endoalveolar crest was in all cases located just below the 3rd molar tooth. Its distal border commenced at the distal border of the 3rd molar alveolar bone and formed a distinct crest or ridge passing forward and parallel to the crest of the alveolar bone. It terminated just lingual and a little below the mesiolingual surface of the 3rd molar tooth.

The lingual nerve groove is thus formed by the endoalveolar crest above and the mylohyoid ridge below. In some cases there was, in addition,a quite distinct indentation in the base of the concavity between the two ridges of bone. On occasions the crest was barely perceptible, whereas in a few specimens it was composed of a linear collection of prominent and fused tubercles (Fig. 35). In the latter case the crest would have been easily

Fig. 35. A series of prominent tubercles merging together to constitute the crest.

Fig. 36. In the neonate the crest is located just distal to and below the last molar tooth germ.

palpable in the living state, whereas in most cases the mucoperiosteal covering would mask the crest when it was only modestly expressed. The 3 edentulous Caucasian mandibles displayed similar features to the edentulous Australian Aboriginals and they are not described as a separate group.

Australian Aboriginal mandibles

On examining the Australian Aboriginal collection there was a distinct crest present in the 2 neonate mandibles examined. These 2 specimens together with 9 adolescent, 23 mature dentate adults and 14 partially or wholly edentulous skulls, demonstrated the changing position of the crest from birth to old age. At birth the crest is located just distal to, and below the last molar tooth-germ on the dorsal aspect of the mandible (Fig. 36). As growth progresses it maintains its position always just distal to the last erupted molar tooth (Fig. 37). In the mature dentate adult it remains always a little below, and continuing just beyond, the 3rd molar tooth (Fig. 38). As in the Caucasian skulls it was occasionally barely perceptible, whereas in the majority of the skulls examined it was readily demonstrated.

After the posterior teeth are lost the crest at first remains distinct, maintaining its relationship just below the level of the remaining alveolar ridge. Both ridge and crest continue to move downwards as the ridge resorbs, until ultimately the crest reaches and becomes one with the mylohyoid ridge. Eventually, when resorption has become quite severe, the mandibular body in this region appears reduced to a concave ribbon of bone, bounded medially and slightly above by the fused mylohyoid line, sloping down to the remaining alveolus and rising again laterally to becomethe external oblique ridge. It is at this stage of resorption that the mylohyoid ridge appears to run as a continuous spine from the coronoid process downwards and forwards; the separate structures of the internal

Fig. 37. The crest maintains its relationship during growth, always remaining distal to the last erupted molar.

Fig. 38. The typical appearance of the crest in the mature adult.

oblique ridge of the ramus, the endoalveolar crest and the mylohyoid ridge are no longer distinguishable (Fig. 39).

Fig. 39. Following gross resorption there is no longer a clear distinction between the three merged structures viz: endoalveolar crest, mylohyoid ridge and temporal crest.

Primate skulls

There was a wide variation of expression of the crest amongst the primate mandibles. In *Hylobates lar* it closely resembled the human form in both shape and location (Fig. 40). In *Pongo pygmaeus* it was a well-formed spine, sharply projecting laterally and distally from its base, just below and distal to the 3rd mandibular molar (Fig. 41). In *Cercopithecus mitis* it was located between the 3rd molar and the ascending ramus and took the form of a distinct tubercle of bone arising vertically from the mandible (Fig. 42). In the case of *Macaca nigra* the crest swept up to form a vertical peak behind the third molar (Fig. 43).

Cadavers - preserved and post-mortem

It has been mentioned that the flap design described by the author in Section 3 may be considered to constitute a danger to the lingual nerve with respect to the first part of the incision through the retromolar pad.

With the vulnerability of the lingual nerve in mind, all of the incisions on the cadavers were made to expose the mandible, and to represent the incisions that would be made during the operation for smoothing the mylohyoid ridge (Fig. 44).

The lingual nerve enters the floor of the mouth from beneath the superior constrictor muscle and lies in a groove on the mandible between the endoalveolar crest and the mylohyoid ridge. It then passes forward and medially on the surface of the mylohyoid muscle, just beneath its covering of mucous membrane. An incision that bisects the retromolar pad and passes downward and outward toward the external oblique ridge will not endanger the nerve, firstly because the crest protects the nerve in this area and secondly because the number 15 scalpel blade used is directed away from the nerve itself. An incision made further back than halfway through the retromolar pad however, particularly if the crest and ridge have fused, may endanger the nerve because as the crest and the mylohyoid ridge fuse, the

Fig. 40. The crest in this primate mandible (*Hylobates lar*) closely resembles the human form.

Fig. 41. The crest expressed as a well formed spine, projecting sharply laterally and distally from its base in *Pongo pygmaeus*.

Fig. 42. A distinct tubercle arising vertically, just distal to the third molar (*Cercopithecus mitis*).

Fig. 43. The crest sweeping upwards to form a vertical peak behind the third molar (*Macaca nigra*).

nerve becomes "exposed" in its more distal path and loses the protection of the crest (see Fig. 34).

In the limited time available during autopsy, it was not possible to dissect the retromolar tissues in much detail. It was possible however, to note that in all instances there were muscle fibres attached to the crest, even though in two instances, they were scanty (Fig. 45). It was presumed that these were fibres of the lingual attachment of the superior constrictor muscle (lingual slip of superior constrictor). Likewise it was presumed that the crest forms the bony attachment for the pterygo-mandibular raphé. Further dissections are planned to verify these suppositions.

Fig. 44. Outline of initial incision on mandible of preserved cadaver.

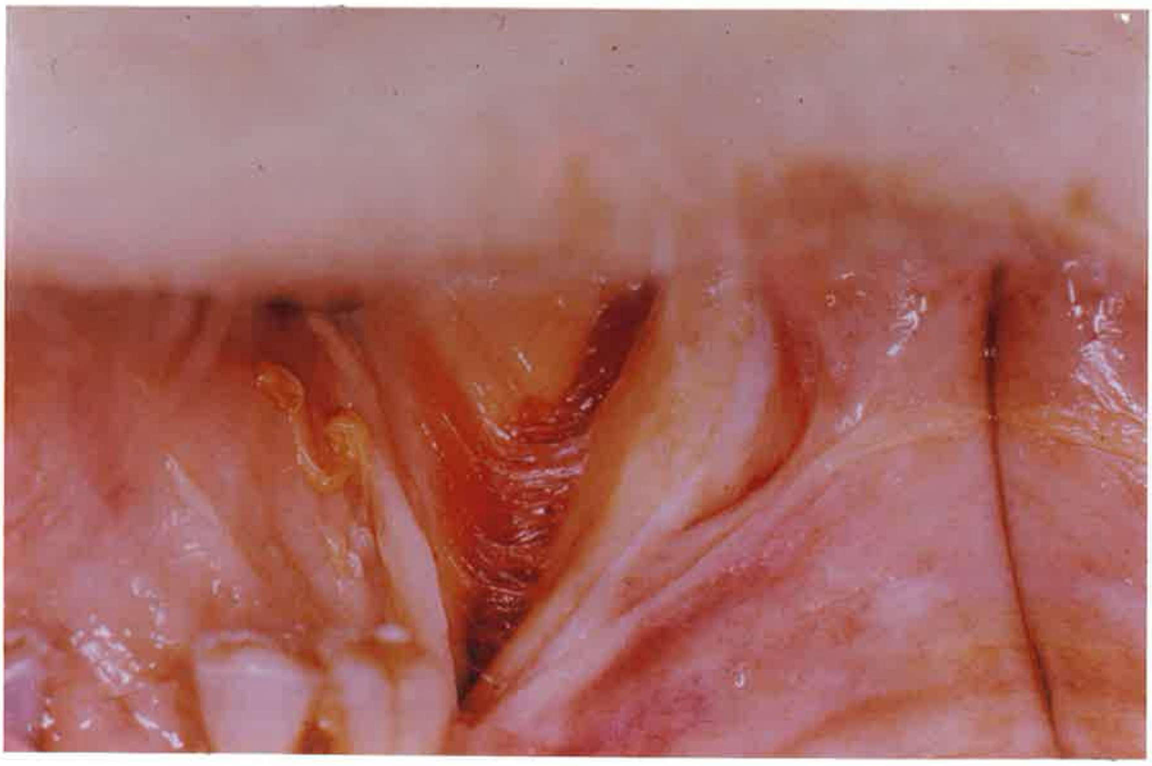


Fig. 45. Muscle fibres exposed on reflection of flap in the fresh cadaver.

DISCUSSION

Orientation of structures in the area surrounding the mylohyoid ridge

Much of the literature regarding the relationships of the structures investigated in this study is conflicting. One explanation is that anatomists tend to make their observations on dissected cadavers, whereas clinical observations are made on a living patient who is usually upright in the dental chair, and where the tissues are soft and pliable. In the supine position on an autopsy slab the tongue and the floor of the mouth, together with all of the soft tissues attached to the mandible, fall back against the pharynx and appear to change their relationships to one another. For example, the lingual nerve in a subject lying in the supine position (or a cadaver) appears to leave the mandible almost at a right angle to the mandible. However, in the upright patient the nerve follows a path running obliquely forward and medially to enter the tongue on its lateral border.

Function of the endoalveolar crest

It seems reasonable to consider that the endoalveolar crest, whether or not it is expressed as a bold and discreet entity, has specific functions. Despite the statement by Waite (1978) in his description of the crest: "There is no muscle attachment to it", there is little doubt in this author's mind that it constitutes the origin of part of the superior constrictor muscle as suggested by Huelke (1973). All bony origins of muscles are recognisable on the dried skeleton and their sizes and shapes are in proportional relationship to the muscle size and function. As the lingual nerve leaves the protection of the soft tissues of the mandible beneath the crest, prior to entering the tongue, the crest constitutes a bony protection to the nerve during its vulnerable "exposure" within the oral cavity. Any unprotected nerve trunk in the oral cavity would be at risk from a variety of foodstuffs eaten by primates. This could include not only bony spicules, but also sharp pieces of vegetation.

Some of the larger apes, such as the chimpanzee and gorilla are known to supplement their normal diet of leaves, insects and very small animals by organising a hunt for larger animals to augment the menu. Deer and even small monkeys are stalked and ambushed by the Group And this activity is followed by a frenzy of feasting. The captured animal is torn limb from limb and devoured in large chunks.

The mandibles of the larger apes studied had particularly large endoalveolar crests that not only may afford protection to the lingual nerve, but could also reflect comparatively large superior constrictor muscle attachments. It could be argued that the coarse diet enjoyed by these animals, consisting of leaves, fruit and insects, occasionally supplemented by tough raw meat, would require very strong pharyngeal muscles to aid deglutition.

In humans there is also a wide variation in expression of all skeletal muscle attachments. It is possible that in some individuals the variety in quality and quantity of foods ingested, plus differences in bolus lubrication, cause a more forceful swallowing effort, which could lead to localised hypertrophy of the bony attachment of the muscles of deglutition. Since human beings are very selective in their choice of food, this may explain why in some individuals the crest is readily identified, whereas in others it is only faintly discernible.

Finally, it is suggested that as the term "endo-" implies "within", it may be more appropriate to rename this crest the ***end***alveolar crest as it marks the end of the mandibular body and is certainly not within the alveolar bone.

SECTION 5

SUMMARY AND CONCLUSIONS

This study aimed at describing and evaluating the consequences of simple surgical smoothing of the sharp bony ridges on the lingual surface of the mandible and investigating the anatomical and clinical variations of the retromolar area. Having performed many hundreds of these operations over a fifteen year period, from 1963 to 1978, the author, in 1978, decided to record the outcome of this procedure over an eight year period from 1978 to 1985.

Every patient referred to the author's practice for the provision of full dentures during that period was included in the study. The study group totalled 610, ranging in age from 23-89 years, and consisting of 173 males and 437 females. After counselling and advice, 89 patients declined any further treatment and were discharged. The remaining 521 (145 males and 376 females) fell naturally into three groups. Group A (247) were judged to be quite "normal" and were provided with full dentures without surgery. Group B (183) required and accepted surgery prior to denture construction. Group C (91) were advised to have surgery but, for various reasons declined, accepted dentures only. This last group (C) was subdivided into five sub-groups according to the reasons for non-surgical intervention.

The examination of patients, surgical procedures and construction of prostheses were standardized and, with the exception of a small number of surgical procedures, all clinical and laboratory procedures were carried out by the author alone. Each patient was instructed to return should they experience any discomfort after treatment. The performance of each individual was assessed according to the number of post-insertion visits required to make the patient comfortable. In prosthodontic circles, it is accepted universally that two post-insertion visits for adjustment leading to complete comfort, signifies a satisfactory outcome. Therefore two visits were accepted as the norm.

The hypothesis was that Group A (normal), i.e. patients whose mylohyoid ridges did not appear to constitute a potentially discomforting factor, would probably require fewer post-insertion visits than the other two groups, and that Group C would probably require the greatest number of post-insertion adjustments, i.e. Group A should perform the best, Group B less so, and Group C, the worst.

Analysis of the results showed that in fact Group B (those subjected to simple surgery) performed better than expected, 170 (93%) required up to two visits. Group A did less well, 205 (83%) required up to two visits. Group C performed worst, 68 (75%) only required two visits or less. These observations suggested that simple surgery had been markedly beneficial to the patients' comfort. The influence of other co-factors, including age, sex and any underlying medical condition were also explored.

During the examination of this large group it was noticed that not all of the exostoses which appeared to be the source of discomfort were associated with the mylohyoid ridge, but rather they represented a small projection of bone above and distal to the muscle attachment.

An extensive review of the literature, relating to both descriptive anatomy, pre-prosthetic surgery and oral anatomy revealed only one reference to this bony exostosis. Daniel E. Waite (1978), in his Textbook of Practical Oral Surgery, described the feature as the "endoalveolar crest" and cautioned that it should be removed at the same time as third permanent molars, to prevent future discomfort whether or not a prosthesis was contemplated. This prompted the examination of 52 Caucasian mandibles which all displayed the crest to varying degrees. It was also observed in Australian Aboriginal mandibles examined at the South Australian Museum, as well as several specimens of primate mandibles. It is suggested that as the term "endo" implies "within", it may be more appropriate to rename this crest the "**end**alveolar" crest as it marks the end of the mandibular body and is certainly not within the alveolar bone although it arises from it.

The literature review also indicated that there is little information on the anatomical variability of structures in the retromolar region, either with respect to changes within an individual related to age or loss of teeth or between individuals. During the examination of many hundreds of patients over some 30 years of clinical practice it was noticed by the author that the morphology of the posterior edentulous mandible varies markedly between individuals when compared to textbook descriptions. No figures are available but it was established that the variation between patients divided them into four quite distinct groups; some patients had a prominent but well-rounded mylohyoid ridge, situated well below the ridge crest, which was unlikely to cause discomfort; some patients, in addition to the above, had a distinct endalveolar crest (or spine) situated distal to, and slightly above, the mylohyoid ridge and this is inevitably a source of discomfort; a third Group appeared to have no endalveolar crest but resorption had led to a sharpened mylohyoid ridge which required surgical attention, whilst a fourth group seemed to have a very sharp mylohyoid ridge which continued a long way posteriorly and upwards onto the ramus of the mandible. In the latter group it is difficult to judge where surgical smoothing should cease.

To throw further light on this, dissections of the retromolar region of four formalin-preserved cadavers were performed. In addition, a total of 48 Australian Aboriginal mandibles housed at the South Australian Museum representing dentate and edentulous individuals of varying ages, were also examined.

It would appear that whether or not the endalveolar crest exists, prior to tooth loss and bone resorption, the crest of the edentulous ridge resorbs until level with the mylohyoid ridge. By this time, had an endalveolar crest existed, it would have moved down with the resorbing ridge until it fused with the mylohyoid ridge and was indistinguishable as a discreet entity. In these cases the mylohyoid ridge appears to continue posteriorly until it fuses with the internal oblique line of the anterior border of the coronoid process and there is no indication on these mandibles where the posterior border of the mylohyoid muscle may have terminated. Photographic evidence is included to illustrate this.

It appears that this crest has a specific function, namely that it constitutes the bony origin of the superior constrictor muscle (mylopharyngeus). It also acts as a bony protection to the lingual nerve as it leaves the soft tissues on the inner surface of the mandible prior to entering the tongue. The author contends that the differences in size and expression of the crest are related to the function of the pharyngeal muscles and that they reflect the dietary variations of individuals and species.

To ascertain the relationship of this crest to the nerve, muscles and edentulous ridge, five autopsy specimens were dissected and the findings photographed. Furthermore, to assess whether or not the author's preferred method of surgical smoothing of the mylohyoid ridge posed a potential threat to the integrity of the lingual nerve, particularly in regard to the initial incision, dissections on the autopsy specimens were performed as if mylohyoid ridge surgery was being carried out. In all five specimens, it appeared that the endalveolar crest afforded protection to the nerve and the first incision did not threaten the nerve.

Further dissections are necessary to confirm the observation that in the edentulous mandible the alveolar bone not only resorbs but, in doing so, the relationship of bone to muscle (and other structures, e.g. lingual nerve) and the length and shape of the muscles also must alter.

It is noted that much of the literature regarding the relationship of the structures investigated in this study is conflicting. One explanation may be that anatomists tend to make their observations following dissection of preserved cadavers whereas clinical observations are frequently made on the living patient who is upright in the dental chair. In the reclined supine position the posterior tongue and floor of mouth, together with all soft tissues attached to the mandible, fall back against the pharynx and appear to change in their relationships to one another. For example, the lingual nerve in the cadaver appears to leave the mandible to pass into the tongue, almost at a right angle to the mandible, whereas in the upright patient the nerve follows a path which runs obliquely forward and medial, to enter the tongue on its lateral border.

Further investigation is clearly warranted.

REFERENCES

Atwood D.A. A cephalometric study of the clinical rest position of the mandible. Part II, the variability in the rate of bone loss following the removal of occlusal contacts. J. Pros. Dent. 1957; 7: 544-552.

Atwood D.A. Some clinical factors related to rate of resorption of residual ridges. J. Pros. Dent. 1962; 12: 441-450.

Atwood D.A. Clinical cephalometric and densitometric study of reduction of residual ridges. J. Pros. Dent. 1971; 26 : 280-295.

Bailey P.H. and Bays R.A. Evaluation of long-term sensory changes following mandibular augmentation procedure. J. Oral and Maxillofac. Surg. 1984; 42: 722-727.

Barker B.C.W. Anatomy of the hard and soft tissues of the oral cavity. Ann. Aust. Coll. Dent. Surg. 1969; 2: 22-38.

Barker B.C.W. Anatomical considerations in full denture construction. Aust. Soc. of Pros. Bulletin 1979; 9: 3-34.

Bassett C.A.L., Pawluck R.J. and Pilla A.A. Augmentation of bone repair by inductively coupled electromatnetic fields. Science 1974; 184: 575-578.

Bitter K. Bone transplants from the iliac crest to the maxillo-facial region by the microsurgical technique. J. Maxillofac. Surg. 1980; 8: 210-216.

Björk A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. J. Dent. Res. 1963; 42: 400-411.

Block M.S. and Kent J.N. Long-term radiographic evaluation of hydroxylapatite augmented alveolar ridges. J. Oral and Maxillofac. Surg. 1984; 42: 793-798.

Boucher Louis.J. Injected silastic for tissue protection. J. Pros. Dent. 1965; 15: 73-82.

Boyne P.J. Osseous repair of the postextraction alveolus in man. J. Oral Surg. 1966; 21: 805-813.

Boyne P.J. and Kruger G.O. Fluorescence microscopy of alveolar bone repair. J. Oral Surg. 1962; 15: 265-271.

Brons R., Bosker H. and Van Dijk L. Visor osteotomy and vestibuloplasty - a one stage procedure: a preliminary report. Int. J.Oral Surg. 1977; 6: 127-131.

Brown L.J. A surgical solution to a lower denture problem. Br. Dent. J. 1953; 215-216.

Bruce R. and Strachan D. Fractures of the edentulous mandible: The Chalmers J. Lyons Academy study. J. Oral Surg. 1976; 34: 973-979.

Caldwell J.B. Lingual ridge extension. J. Oral Surg. 1955; 13: 287-289.

Celesnik F. Intraoral osteoplastic operations. Acta. Chir. Plast. 1963; 5: 266-273.

Chang C.S., Matukas V.J. and Lemons J.E. Histologic study of hydroxylapatite as an implant material for mandibular augmentation. J. Oral and Maxillofac. Surg. 1983; 41: 727-737.

Clementshitch F. Cited in Pichler H. and Trauner R. Editors: Mund-und Klieferchirurgie. Berlin. 1948.

Cooley D.O. Method for deepening the mandibular and maxillary sulci to correct deficient edentulous ridges. J. Oral Surg. 1952; 10: 279-289.

Curtis T.A. and Ware W.H. Autogenous bone graft procedures for atrophic edentulous mandibles. J. Pros. Dent. 1977; 36: 366-379.

Davis W.H., Delo R.I. and Weiner J.R: Transoral bone-graft for atrophy of the mandible. J. Oral Surg. 1970; 28: 760-765.

Dekker J.G. and Tideman H. Histological study of a free mucosal graft from the cheek used in preprosthetic surgery. Int. J. Oral Surg. 1973; 2: 284-289.

Desjardins R.P. Hydroxylapatite for alveolar ridge augmentation: indications and problems. J. Pros. Dent. 1985; 54: 374-383.

Dovitch V. and Herzberg F. A radiographic study of the bony trabecular pattern in the mandibular rami of certain herbivores, carnivores and omnivores. Angle Orthodont. 1968; 38: 205-210.

Donoff R.B. Biological basis for vestibuloplasty procedures. J. Oral. Surg. 1976; 34: 890-896.

Downton D. Mylohyoid ridge resection. The Dent. Rec. 1954; 72: 212-214.

Du Brul E.L. Sicher and Du Brul's Oral Anatomy. 8th Ed. Ishiyaku EuroAmerican, St Louis. 1990.

Enlow D.H. Growth of the face in relation to the cranial base. Europ. Orthod. Soc. 1968; 44: 321-325.

Enlow D.H. and Hunter W.S. The growth of the face in relation to the cranial base. Europ. Orthodont. Soc. Rep. Congr. 1968; 44:321-325.

Enlow D.H. Facial Growth. 3rd Ed. W.B.Saunders Co. Philadelphia. 1990.

Esser J.F. Studies in plastic surgery of the face. Ann. Surg. 1917; 65: 297. (Abstract).

Fazili M., Von Overvest-Eerdmans G.R. and Vernooy A.M. Follow-up investigation of reconstruction of alveolar process in the atrophic mandible. Int. J. Oral Surg. 1978; 7: 400-404.

Fitzpatrick B.N. A comparative study of some implant materials. Part 1. Aust. Dent. J. 1968; 13:360-362. Part 2. Aust. Dent. J. 1968; 13: 422-434.

Fitzpatrick B.N. Free full thickness mucosal grafts in the mouth. Aust Dent. J. 1976; 21: 131-135.

Fitzpatrick B.N. Current concepts in the surgical management of the atrophic mandible. Aust. Dent. J. 1978; 23: 344-349.

Fitzpatrick B.N. Visor/sandwich osteotomy - progress report. Int. J. Oral Surg. 1981; 10: 87-92.

Frost D.E., Fonseca R.J. and Burkes E.J. Healing of interpositional allogenic lyphilized bonegrafts following total maxillary osteotomy. J. Oral Maxillofac. Surg. 1982; 40: 776-786.

Gamzer H. Die wiedherstellung des vestibulum oris nach schussverletzing der kiefer. Deutsche Monat. Zahn. 1916; 43: 380.

German J., Wooley T., Achuer B., Furnas D. and Bartlett R. Porcine Xenograft burn dressings. Arc. Surg. 1972; 104: 806 - 809.

Gerry R.G. Alveolar ridge reconstruction with osseous autograft. Report of a case. J. Oral Surg. 1956; 14: 74 -78.

Gianelly A.A. and Moorees C.F. Condylectomy in the rat. Arch. Oral. Biol. 1965; 10: 101-106.

Gillies H.D. Plastic surgery of the face. Oxford University Press, London. 1920.

Gongloff R.K. and Montgomery C.K. Experimental study of the use of the collagen tubes for implantation of particulate hydroxylapatite. J.Oral and Maxillofac. Surg. 1985; 43: 845 -849.

Gongloff R.K. and Lee R. Collagen tube containers in alveolar ridge augmentation. J. Pros. Dent. 1989; 61: 722-726.

Gwynne-Evans E. Organisation of the oro-facial muscles in relation to breathing and feeding. Br. Dent. J. 1951; 91: 135-142.

Guernsey L.H. Free mucosal grafts in major reconstructive oral surgery. Trans. 4th Int. Congr. Oral Surg. 1973; p.198.

Hall H.D. and O'Steen A.N. Free grafts of palatal mucosa in mandibular vestibuloplasty. J. Oral Surg. 1970; 28: 565-574.

Harle F. Visor osteotomy to increase the absolute height of the atrophied mandible: a preliminary report. Int. J. Maxillofac. Surg. 1975; 3: 257-260.

Hillerup S. Mandibular vestibuloplasty using oral mucosa. 8th Int. Conf. Oral Surg. 1984; Chicago, Quintessence 17.

Hopkins R. Preprosthetic Oral Surgery. Wolfe Medical Publications, London. 1987.

Huelke D.F. Selected dissections of the facial regionsfor advanced dental students. 6th Ed. The Overbeck Co., Ann Arbor, Michigan. 1973.

Humphrey G.M. Result of experiments on the growth of the jaw. Brit. J. Dent.Surg. 1863; IV: 548-550.

Hupp J.R. and Tyson J.A. Study of Interpore 200 (block hydroxylapatite) for alveolar ridge augmentation. Abstracts from 1st International Congress on Preprosthetic Surgery, May 1985.

Jaul D.H., McNamara J.A. and Carlson D.S. A cephalometric evaluation of edentulous Rhesus monkeys (Macaca mulatta): A long-term study. J. Pros. Dent. 1980; 44: 453-460.

Johnston L.E. Jnr. The functional matrix hypothesis: Reflections in a jaundiced eye. In: Factors Affecting the Growth of the Midface. McNamara, J.A. Jnr., Monograph 6, Caniofacial Growth Series. Centre for Human Growth and Development. Ann Arbor, Michigan. 1976.

Kazanjian V.H. Surgical operations as related to satisfactory dentures. Dental Cosmos. 1924; 66: 387-391.

Kelly E. Changes caused by a mandibular removable partial denture opposing a maxillary removable complete denture. J. Pros. Dent. 1972; 27: 140-150.

Kelsey C.C. Alveolar bone resorption under complete dentures. J. Pros.Dent. 1971; 25: 152-161.

Kent J.N., Zide M.F., Quinn J.H., Jarcho M., Finger I.M. and Rothstein S.S. Correction of alveolar ridge deficiencies with non-resorbable hydroxylapatite. J. Am. Dent. Ass. 1982; 105: 993-1001.

Kent J.N., Quinn J.H., Zide M.F., Guerra L.R. and Boyne P.J. Alveolar ridge augmentation using a non-resorbable hydroxylapatite with or without autogenous cancellous bone. J. Oral and Maxillofac. Surg. 1983; 41: 629-634.

Kilner T.P. and Jackson T. Skin-grafting in the buccal cavity. Br. Dent. J. 1921; 148: 1094-1096.

Koski K. and Rönning O. Growth potential of transplanted components of the mandibular ramus of the rat. Suom. Hammaslaak. Toim. 1965; 61: 292-297.

Knolle G. and Pfeiffer D. Erfahoungen mit der oberkiefer-vorhofplastik. Ergebuuisser einer nachuntersuchung. Deutsch Zahn. Z. 1966; 21: 521-527.

Kribbs P.J. Comparison between mandibular bone in normal and osteoporotic women. J. Pros. Dent. 1990; 63: 218-222.

Kribbs P.J., Smith D.E. and Chesnut C.H. Oral findings in osteoporosis. Part 1. Measurement of mandibular bone density. J. Pros. Dent. 1983; 50: 576-579.

Kribbs P.J., Smith D.E. and Chesnut C.H. Oral findings in osteoporosis. Part 2. Relationship between residual ridge and alveolar bone resorption and generalised skeletal osteoporosis. J. Pros. Dent. 1983; 50: 719-724.

Kribbs P.J., Chesnut C.H., Ott S.M., and Kilcoyne R. Relationships between mandibular and skeletal bone in an osteoporosic population. J. Pros. Dent. 1989; 62: 703-707.

Kribbs P.J., Chesnut C.H., Ott S.M., and Kilcoyne R. Relationships between mandibular and skeletal bone in a population of normal women. J. Pros. Dent. 1990; 63: 86-89.

Kruger G.O. Textbook of oral surgery. The C.V. Mosby Co., St Louis. 1968.

Kuij van der, P., Vingerling P.A., Groot de, K. and Sillevis Smitt P.A. Non-invasive treatment of extraction wounds in dogs by electro-magnetic stimulation. J. Bioeng. 1978; 2: 557-565.

Kuij van der, P., Vingerling P.A., Sillevis Smitt P.A., Groot de, K. and Graaff de, J. Reducing residual ridge reduction. Reconstr. Surg. Traumatol. 1985; 19: 98-105.

Lane S.L. Plastic procedures as applied to oral surgery. J. Oral Surg. 1958; 489-492.

Laskin D.M. Surgical aids in orthodontics. Dent. Clin. N. Amer. 1968; 509-524.

Last R.J. Anatomy regional and applied. 8th Ed. Churchill Livingstone, London. 1990.

Lawson W.A. Objectives of preprosthetic surgery. Br. J. Oral Surg. 1972; 10: 178-188.

Lekkas K. Absolute augmentation of the mandible. Int. J. Oral Surg. 1977; 6: 147-152.

Lekkas K. and Wes B.J. Absolute augmentation of the extremely atrophic mandible. J. Maxillofac. Surg. 1981; 9: 103-108.

Limborgh van, J. A new view on the control of the morphogenisis of the skull. Acta. Morphol. Neerl. Scand. 1970; 8: 143-149.

Listgarten M.A. and Helden D. Relative distribution of bacteria at clinically healthy and periodontically diseased sites in humans. J. Clin. Periodont. 1978; 5: 115-132.

MacIntosh R.B. and Obwegeser H.L. Preprosthetic surgery: A scheme for its effective employment. J. Oral Surg. 1967; 25: 397-413.

Maloney P.L., Shepherd N., Doku H.C. and Murnane T. Free buccal mucosal grafts for vestibuloplasty. J. Oral Surg. 1972; 30: 716-721.

McNamara J.A. Jnr. Studies of adaptation to experimental change in form and growth of the Rhesus monkey. Am. J. Orthodont. 1972; 62: 317-318.

McNamara J.A. Jnr. and Graber L.W. Mandibular growth in the Rhesus monkey (Macaca mulatta). Am. J. Phys. Anthropol. 1975; 42: 15-24.

Mercier P. and Vinet A. Local and systemic factors in residual alveolar ridge atrophy. Int. J. Oral Surg. 1981; 10: 65-70.

Mercier P., Cholewa J., Djokovic S., Masella R. and Vinet A. Mandibular ridge augmentation and resorption with various visor procedures. J. Oral Maxillofac. Surg. 1982; 40: 709-713.

Mitzutani H. and Ishihata N. Decrease and increase in residual ridge after extraction of teeth in monkey. Pt. 1. Bull. Tokyo Med. Dent. Univ. 1976; 23: 157-168.

Moskovitch L. Ueber die verplanzung thierscher epidermishaeppchen in die mundhoele. Arch. Klin. Chir. 1916; 108: 216-219.

Moss M.L. and Rankow R.M. The role of the functional matrix in mandibular growth. Angle Orthodont. 1968; 38: 95-103.

Moss M.L. and Salentjin L. The primary role of functional matrices in facial growth. Am. J. Orthodont. 1969; 55: 566-577.

Moyers R.E. Handbook of orthodontics 4th Ed. Year Book Medical Publishers, Chicago. 1988.

Obwegeser H. Die submukose vestibulumplastik. Deutsch Zahnarztl, Zurich. 1959; 14: 749-756.

Obwegeser H. Die totale mundbodenplastik. Schweiz Mschr. Zahnheikd. 1963; 565-572.

Obwegeser H. Weitera efahrungen mit der aufbauenden kammplastik. Schweiz Monat. Zahn. 1967; 77: 1002-1009.

Peterson L.J. Augmentation of the residual ridge by a modified visor osteotomy. J.Oral Maxillofac. Surg. 1983; 41: 332-338.

Peterson L.J. and Slade E.W. Mandibular ridge augmentation by a modified visor osteotomy: Preliminary report. J. Oral Surg. 1977; 35: 999-1004.

Phillips H.B. and Ashley F.P. The relationship between periodontal disease and a metacarpal bone index. Br. Dent. J. 1973; 134: 237-239.

Pickerill H.P. Intra-oral skin-grafting; the establishment of the buccal sulcus. Brit. J. Dent. Sci. 1919; 32: 135-141.

Pietrokovski J. and Massler M. Residual ridge remodelling after tooth extraction in monkeys. J. Pros. Dent. 1971; 26: 119-120.

Propper R.H. Simplified ridge extension using free mucosal grafts. J. Oral Surg. 1964; 22: 469-474.

Roberts B.J. Mylohyoid ridge reductions as an aid to success in complete lower dentures. J. Pros. Dent. 1977; 37: 486-493.

Roberts B.J. The efficiency of the mylohyoid ridge resection in improving success with the complete lower denture. Br. Dent. J. 1977; 142:151-154.

Rosenquist J.B., Baylink D.J. and Burger J.S. Alveolar atrophy and decreased skeletal mass of the radius. Int. J. Oral Surg. 1978; 7: 479-481.

Rumpel C. Die wiederherstellung des vestibulum oris nach schussverletzung der kiefer. Deutsche Zahn. Woch 1916; 19: 262.

Rushton M.A. Growth at the mandibular condyle in relation to some deformities. Br. Dent. J. 1944; 76: 57-68.

Sanders B. and Starshak T.J. Modified technique for palatal mucosal grafts in mandibular labial vestisbuloplasty. J. Oral Surg. 1975; 33:950-952.

Sanders B., McKelvy B. and Kaspar D. Porcine skin xenografts as oral wound dressings in dogs. Ann. Dent. 1978; 37: 12-19.

Sarnat B.G. Post-natal growth of the upper face: some experimental considerations. Angle Orthodont. 1963; 33: 139-161.

Saunders T.R., Gilles R.E. Jnr. and Desjardins R.P. The maxillary complete denture opposing the mandibular bilateral distal-extension partial denture: treatment considerations. J. Pros. Dent. 1979; 41: 124-128.

Schettler D. and Holteman W. Clinical and experimental results of a sandwich technique for mandibular alveolar ridge and augmentation. J. Maxillofac. Surg. 1977; 5: 199-202.

Schmid E. Die aufbauende kiefer kammplastik. Oest. Z. Stomat. 1954; 51: 582-587.

Schuchardt K. Die epidermistransplatation bei der mundvorhofplastik. Dtsch. Zahnarztl. Zurich. 1952; 7: 364-369.

Schuchardt K. and Frolich D. Die restaurative alveolar- kammplastik. From Meyer W. and Schuchardt K. Eds. Zahn Mund-Kieferheilke. Ein handbuch die zahnarzliche. Haup, K. Munchen. 1959.

Shen K. and Gongloff R.K. Prevalence of combination syndrome among denture wearers. J. Pros. Dent. 1989; 62: 642-644.

Shepherd N.S., Moloney P.L. and Doku H.C. Fenestrated palatal mucosal grafts for vestibuloplasty. J. Oral Surg.1975; 33: 34-37.

Silverberg M., Singh M. and Sreekanth S. Use of polyglycolic acid mesh to confine particulate hydroxyapatite for augmentation of bone in the rat. J.Oral and Maxillofac. Surg. 1986; 44: 877-886.

Sjaba J. Methode zur verhinderüng des verwachsung der durchtrennten mund schleimhaut. Oest. Viertel. Jares. Zahn. 1916; 43: 244.

Smiler D., Radack K., Bilovsky P. and Montemarano P. Dermal grafts - a versatile technique for oral surgery. Oral Surg. 1977; 43: 342-348.

Spengler D.E. and Hayward J.R. Study of sulcus extension wound healing in dogs. J. Oral Surg. Anes. and Hosp. D. Serv. 1964; 22: 413-421.

Sperber G.H. Craniofacial Embryology. Dental Practitioner Handbook, 15, Fourth Edition. Wright, Toronto. 1989.

Starshak T.J. and Sanders B. Preprosthetic oral and maxillofacial surgery. The C.V. Mosby Co. St Louis. 1980.

Steinhauser E.W. Free transplantation of oral mucosa for improvement of denture retention. J. Oral Surg. 1969; 27: 955-961.

Steinhauser E. W. and Obwegeser H. Rebuilding the alveolar ridge with bone and cartilage autografts. Trans. Congr. Int. Ass. Oral Surg. 1967; Copenhagen, Munksgaard.

Stoelinga P.J.W., Blijdorp P.A. and De Koomen H.A. Augmentation of the strophic mandible with interposed bone and hydroxylapatite. Abstr. from 1st Int. Congress on Preprosthetic Surgery. May 1985.

Tallgren A. Changes in adult face height due to ageing, wear and loss of teeth and Pros. treatment: A Roentgen cephalometric study mainly on Finnish women. Acta. Odont. Scand. 1957; 15: Suppl 24, 1-122.

Tallgren A. The effect of denture wearing on facial morphology; a 7 year longitudinal study. Acta. Odont. Scand. 1967; 25: 563-592.

Tallgren A. Positional changes of complete dentures; a longitudinal study. Acta. Odont. Scand. 1969; 27: 539-561.

Tallgren A. Alveolar bone loss in denture waerers as related to facial morphology. Acta. Odont. Scand. 1970; 28: 251-270.

Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed longitudinal study covering 25 years. J. Pros. Dent. 1972; 27: 120-131.

Terry B.C., Albright J.E. and Baker R.D. Alveolar ridge augmentation in the edentulous maxilla with use of autogenous ribs. J. Oral Surg. 1974; 32: 429-434.

Thoma K.H. Oral Surgery, 3rd Ed. The C.V.Mosby Co. St.Louis.1958.

Thoma K.H. and Holland D.J. Atrophy of the mandible. Oral Surg., Oral Med., Oral Path. 1951; 4: 1477-1495.

Topazian R.G. and Hammer W.B. Surgical correction of skeletal deformities of the jaws. J. Can. Dent. Ass. 1971; 44: 13-18.

Trauner R. Alveoplasty with ridge extensions on the lingual side of the lower jaw to solve the problem of a lower dental prosthesis. Oral Surg. 1954; 5: 340-347.

Trieger N. and Herzberg F. Radiographic changes in the rami of edentulous human mandibles. J. Geront. 1970; 24: 302-304.

Van de Mark T.B. Weinberg S. and Zosky J.G. Pathological fracture resulting from mandibular atrophy: Report of two cases. J. Can. Dent. Ass. 1969; 35: 98.

Vingerling P.A., Bronckers A.L.J.J., Woltgens J.H. and Groot de, K. Tooth germs of Mesocricetus Auratus cultured in a pulsing electromagnetic field. Reconstr. Surg. Traumat. 1985; 19: 93-97.

Volchansky, A. and Makings, E. A new mandibular landmark? J. Dent. 1984; 3: 221-224.

Waite D.E. Textbook of Practical Oral Surgery. 2nd Ed. Lea and Febiger, Philadelphia. 1978.

Wang J.H., Waite D.E. and Steinhauser E. Ridge augmentation - an evaluation and follow-up report. J. Oral Surg. 1976; 34: 600-602.

Ward V.J. and Manson J.D. Alveolar bone loss in periodontal disease and the metacarpal index. J. Periodont. 1973; 44: 763-769.

Willard A.T. Preparing the mouth for full sets of artificial teeth. Dent. Newsletter. 1853; 6: 238-239.

Wood M. and Hale H. The use of pigskin in the treatment of thermal burns. Am. J. Surg. 1972; 124: 720-723.

Zeltser C., Massella R., Cholewa J. and Mercier P. Surgical and prosthodontic residual ridge reconstruction with hydroxyapatite. J.Pros. Dent. 1989; 62: 441-448.