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AIR ROTOR INTERPROXIMAL REDUCTION
THE DEVELOPMENT OF A BUR FOR USE IN POSTERIOR TEETH

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A THESIS SUBMITTED IN PARTIAL REQUIREMENT FOR THE DEGREE OF MASTER OF DENTAL SCIENCE

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SUMMARY

A technique of interproximal reduction for posterior teeth using an air rotor has been devised and demonstrated. This involves the customising of commercially available tungsten carbide burs and using them to reduce enamel on the interproximal surfaces of posterior teeth. The surface of the tooth adjusted in this way is smoother than the surface obtained by adjusting with a finishing diamond. In addition, a marginal ridge form can be developed which allows for easy finishing with fine abrasive polishing discs, so as to leave a surface which approximates that of the original tooth surface for marginal ridge form and smoothness.

Where any irreversible operator technique is to be used, it must be used judiciously in well diagnosed cases. This technique of interproximal reduction using a customised tungsten carbide bur in an air rotor is best used after reference to bite-wing X-rays. It is also important that all teeth be upright, aligned and de-rotated before interproximal reduction is carried out. If appropriate, separators (0 modules) should be placed interproximally three to four days prior to interproximal reduction, so as to displace gingival tissue close to the contact area. In general, 0.5 mm of enamel can be removed from each
approximal surface. However, it is important to be aware of the morphology of the teeth which are being altered as the reduction is not just at the contact area, but needs to be carried around onto the lingual or palatal surface and to some extent onto the buccal surface of the tooth, to avoid subsequent gingival problems. If used appropriately, there is no requirement for local anaesthesia; patient acceptance of the procedure is good and the after effects (providing there has been no dentine notching or inadvertent tissue laceration) are negligible. As with any procedure requiring alteration of tooth morphology, it is important that good oral hygiene be maintained, appropriate fluoride applications be made and that regular gingival tissue assessments are undertaken.
CHAPTER 1. INTRODUCTION

"Most orthodontic patients require reduction of tooth substance before starting appliance therapy" (Begg and Kesling, 1977, p.75). This can be achieved by extracting teeth, by reducing the mesio-distal width of teeth (proximal trimming - Begg and Kesling, 1977 p.656, ), (reproximation - Lyngoy, 1987), (proximal stripping - Vickers, 1982), (air-rotor stripping - Sheridan, 1985), or by a combination of both procedures. Elective tooth extraction is often an emotive issue for both the operator and patient and at times post-treatment dissatisfaction has been correctly or incorrectly attributed to this means of treatment. However, in selected cases, the reduction in the mesio-distal length of the dental arch, brought about by removing a little tooth substance from the mesial and distal surface of each tooth, sufficient to give a stable orthodontic result, can lessen the emotional involvement of tooth loss and at the same time closely simulate what Begg and Kesling (1977) describe as attritional occlusion. This type of dental arch length reduction also allows for maintenance of the unique occlusal interdigitation and the confluence of marginal ridge integrity that are otherwise lost when, for example, second bicuspids are placed adjacent to cuspids.
The aim of this work was to develop a system suitable for an occlusal approach to air-rotor separation (ARS) between the approximal surfaces of posterior teeth.

Some effects of enamel surface roughness were demonstrated by earlier work in this dental school (Vickers, 1982) undertaken as an investigation of proximal stripping. This work involved a limited study of the effects of interproximal stripping aids, as observed at the light microscopic level, on surface enamel. Such conventional techniques using hand-held abrasive strips (e.g. tooth stripper, Lancer Pacific Inc., Carlsbad, California, USA) and handpiece mounted rotating diamonds (e.g. Horico, Hopf, Ringleb and Co. GmbH and CIE, Berlin, West Germany) and abrasive discs (e.g. Sof-lex, 3M Australia Pty Limited, Sydney, Australia) are normally limited to the anterior teeth. With the development of full-arch orthodontic appliance bonding systems, and their gradual acceptance by the profession - perhaps attributable to the ever-improving adhesive systems - the interproximal surfaces of all teeth can now be available for reduction at any time.

Sheridan (1985; 1987) has advocated a technique whereby the interproximal enamel is removed to create space using water-cooled tungsten carbide burs in an air-rotor handpiece. The amount of enamel reduction can be directly
correlated with the amount of crowding pre-existing in a malocclusion such that a pre-determined amount of space can be created and the case treatment planned accordingly: for example, the use of a diagnostic set-up as proposed by Kesling (1956). However, for successful orthodontic reproximation, the altered tooth surfaces should resemble the original interproximal morphology with regard to marginal ridge height, embrasure form and contact with approximal teeth, differing only in overall reduction in mesio-distal width of the altered tooth. This is necessary so that successful occlusal function can be maintained and no deleterious gingival or periodontal effects are produced. (for example, food impaction areas brought about by reducing the occlusal height of the contact area).

The Sheridan (1985; 1987) technique is based on the concept that reproximation is suitable for all teeth using conventional commercially available burs. In practice, it soon became apparent that it was a difficult procedure, with considerable risk of notching the teeth interproximally, brought about by the lateral approach (buccal or lingual) to the interproximal area. Moreover, there was no way of ensuring that the smooth integrity of the enamel surface, so necessary for tooth and periodontal health, could be guaranteed.
The work described in this thesis has been focused on the effects of high speed air-rotor alteration of posterior tooth morphology (distal surface of canine to mesial surface of first molar) using an occlusal approach and a customised finishing system developed for ease of operation. This approach takes advantage of the recently released (1987) finishing discs (Sof-lex XT series, 3M Australia Pty Limited, Sydney, Australia). The enamel surface finish and interproximal morphology that can be expected is described and demonstrated, and an alternative technique to that of Sheridan (1985; 1987) is documented.

The following chapters cover, by way of background information in support of posterior reproximation:

(2) the anatomy of the teeth to be altered;
(3) the structure of enamel;
(4) the effect on pulpal tissue of cutting enamel;
(5) the amount of enamel that can be removed;
(6) the effect of fluoride on the altered tooth surface;
(7) periodontal considerations;
(8) indications, precautions and contraindications for interproximal reduction in posterior teeth.
CHAPTER 2. ANATOMY OF THE TEETH TO BE ALTERED

For successful function, teeth require a specific form (Fuller and Denehy, 1984, pp 28.). If no heed is paid to normal tooth form when altering the tooth and its alignment, the dental operator may be creating more damage to the dental mechanism than is being corrected by the dental procedure. For example, marginal ridges between adjacent approximal teeth are designed to hold supporting cusps (Renner, 1985, pp 172.). If, when altering tooth form, this is not preserved, the occlusal function may be impaired by the loss of posterior cusp support. It is therefore important to recognise that for successful interproximal reduction, it is not only the mesio-distal width of a tooth which has to be altered, but also its entire occlusal form; and subsequent occlusal interdigitations need to be considered. The following discussion concerns these aspects of tooth morphology which are considered important when carrying out posterior interproximal reduction.

Orientation provides one of the greatest difficulties to be overcome when describing a tooth. This is because there are no sharp lines of demarcation between the various surfaces. Hence, care should be taken to view a tooth surface normal to the line of vision. Even then, a considerable variation in the minutiae of anatomical
detail exists so that not just one but several specimens should be observed in order that form can properly be appreciated.

Gabriel (1965), in a definitive publication, has described tooth form. The pertinent points of crown shape relative to interproximal stripping and subsequent reproximation are summarised below. These are supported by the works of Woelfel (1984), Fuller and Denehy (1984) and Renner (1985).

2.1 Maxillary canine (cuspid) (Fig 2.1a) - the distal surface of the canine when viewed from the labial aspect flares markedly from the neck of the tooth and rounds into a strong convexity. In this profile, the enamel border at the neck is quite convex. Viewed from the occlusal, the distal and mesial sides converge slightly towards the lingual. At the distal enamel junction, the cemento-enamel margin is concave. The contact area (the generally flat area on a proximal surface of the crown which contacts the adjacent tooth in the arch) is circular in shape and located in the middle third of the distal surface.

2.2 Maxillary first premolar (first bicuspid) (Fig 2.1b) - when viewed from the occlusal, there are two cusps, buccal and lingual, with the lingual cusp being somewhat
Fig 2.1. Diagrammatic representation of selected maxillary teeth: (a) canine, (b) first premolar, (c) second premolar, (d) first molar. (modified from Fuller and Denesy, 1984)
eccentrically placed mesially. The bucco-lingual diameter of the crown is greater than its mesio-distal diameter. Marginal ridges on the mesial and distal sides of the occlusal surface connect the buccal and lingual cusps, with the free edges of the marginal ridges being slightly concave longitudinally. Separating the two cusps is a lingually displaced fissure running mesio-distally which at each end joins shorter transverse fissures running buccally and through to a lesser extent lingually. These bucco-lingual fissures lie along the inner sides of the mesial and distal marginal ridges. A small subsidiary groove often runs from the mesial fissure over the mesial marginal ridge to fade out on the mesial surface of the crown. Occasionally, this similarity occurs on the distal side of the tooth.

The mesial surface of the crown is square in outline and flares outward from the neck in the vertical plane. The occlusal part of the mesial surface is bent in a concave manner due to the displacement of the lingual cusp in a mesial direction. In the cervical half of the central part of this surface there is a wide concavity which extends down the root (canine fossa). The buccal side rounds off onto the buccal surface in a gradual manner near the neck of the tooth, but as the occlusal surface is approached, this becomes more accentuated. The lingual side of this surface rounds off in an even manner onto
the lingual surface. The mesial height of contour is associated with the contact area at the junction of the middle and occlusal thirds. The contact area is roughly circular in shape and is offset to the buccal.

The distal surface of the crown is similar to the mesial surface in outline and outward flare from the neck of the tooth. The surface is slightly convex in all directions except centrally, where it may be flat. As with the mesial surface, the distal surface similarly rounds off onto the other surfaces except for a more extensive curvature where it passes onto the mesially displaced lingual cusp. The distal contact area is larger than the mesial, and is located at a slightly more cervical level, but still at the junction of the occlusal and middle thirds. Its outline is ovoid, and is wider buccolingually than occluso-gingivally.

2.3 Maxillary second premolar (second bicuspid) (Fig 2.1c) - this tooth resembles the general shape of the maxillary first premolar in gross appearance. However, there are many minor points of difference, most of which indicate a more symmetrically shaped tooth. When viewed from the occlusal surface, the two cusps are smaller mesio-distally and appear more separated than the maxillary first premolar. The lingual cusp displacement towards the mesial may be present, but, if so, is slight.
The fissure separating the cusps is usually shorter and more centrally placed.

The mesial surface of the crown has less outward flare from the neck than the maxillary first premolar. The mesial surface is flat bucco-lingually, except where it terminates by rounding off onto the respective surfaces. Both the contact area and marginal ridge are located at a slightly more cervical level than on the mesial of the first premolar.

The distal surface flares out more abruptly from the neck than does the mesial surface. The distal surface is convex in both vertical and transverse directions and contrasts with the flat inclined plane of the mesial surface. Both the distal contact area and marginal ridge are found at a slightly more cervical level than on the distal of the first premolar.

2.4 Maxillary first molar (Fig 2.1d) - the outline of the occlusal surface when viewed occlusally is that of a quadrilateral figure encompassing four cusps. The longest side of the quadrilateral is the mesial, and the second longest is the lingual. The mesio-lingual cusp is the largest of the main cusps, and the disto-lingual usually the smallest. The two buccal cusps are similar in size. However, the mesio-buccal can often be a little larger.
The mesial side of the mesio-buccal cusp is joined to the mesial side of the mesio-lingual cusp by a mesial marginal ridge. The fossa which lies between these cusps and the disto-buccal cusp is called the anterior fossa and usually there is a pit developed in its deepest part. From this pit, a fissure passes mesially towards the mesial marginal ridge where it bifurcates: one fissure extends in a buccal direction along the inner side of the marginal ridge and between it and the base of the mesio-buccal cusp; the other fissure passes lingually in a similar manner between the marginal ridge and the mesio-lingual cusp. A minor groove or fissure may occasionally pass from these fissures over the mesio-marginal ridge and so give the appearance of forming little tubercles on the mesial marginal ridge.

The mesial surface of the crown flares outward overhanging the neck. Centrally near the neck of the tooth, this surface is fairly flat. Elsewhere it is convex, rounding off occlusally onto the mesial marginal ridge and the two mesial cusps, and at the sides onto the buccal and lingual surfaces respectively. The contact area varies from round to somewhat ovoid, and is situated slightly to the buccal, at the junction of the occlusal and middle thirds.

2.5 Mandibular canine (cuspid) (Fig 2.2a) - the distal
Fig 2.2. Diagrammatic representation of selected mandibular teeth: (a) canine, (b) first premolar, (c) second premolar, (d) first molar. (modified from Fuller and Deney, 1984)
surface of the tooth is seen to be slightly concave near the neck and flares slightly distally when viewed from the labial. This flare increases as the junction with the distal incisal edge is approached. When reached, the border abruptly becomes convex and rounds off. The distal surface, when viewed from the occlusal, overhangs the neck. It is fairly flat near the neck but becomes strongly convex incisally where it rounds off into the distal incisal edge. The contact area, found at the junction of the incisal and middle thirds of the distal surface, has a circular shape.

2.6 Mandibular first premolar (first bicuspid) (Fig 2.2b) - the crown of this tooth is the smallest of all the premolars. When viewed from the occlusal surface, it is more circular in outline than the maxillary premolars, with the apex of the large inrolled buccal cusp reaching almost as far lingually as the centre line of the tooth. The lingual part of the crown is poorly developed and much more variable than in the maxillary premolars. Mesial and distal marginal ridges join the respective sides of the two cusps and pass around the outer sides of two pits at the end of a variable mesio-distal fissure. From the buccal sides of these pits, fissures may extend buccally for a little distance between the base of the buccal cusp centrally and the respective marginal ridge laterally. Similarly, from the lingual side of the mesial
pit and occasionally from the distal pit, a small fissure passes over the respective marginal ridge. As a result of the normally small development of the lingual cusp, the occlusal surface in general is very oblique and slopes inward towards the floor of the mouth. However, variations in crown form are not uncommon: for example, the lingual cusp is displaced towards the distal giving the outline of the occlusal surface a triangular appearance, with the base of the triangle towards the mandibular second premolar and its apex towards the canine and buccally; or a deep fissure which is strongly bent around the lingual part of the base of the buccal cusp, and the lingual cusp is so poorly developed as to serve merely as a link between the mesial and distal marginal ridges.

The mesial surface of the crown is convex, flares outward from the neck and converges towards the lingual. The mesial contact area is located in the middle third of the surface, slightly buccally displaced and close to the buccal outline. It is circular to somewhat ovoid in shape. The distal surface of the crown converges towards the lingual about the same amount as the mesial surface, and the marginal ridges are of similar height. However, the distal side flares outward from the neck a little more than the mesial side and is a little more rounded or convex in a vertical direction. The distal contact area
is shaped and located similar to the mesial surface, but occupies a slightly broader area, since it approximates the second premolar.

2.7 Mandibular second premolar (second bicuspid) (Fig 2.2c) - this tooth is larger than the mandibular first premolar and has better developed lingual cusp or cusps. When viewed from the occlusal surface, it is rather more quadrate in outline due to a wider lingual part of the crown, but otherwise the general pattern of this surface, when it possesses a single lingual cusp is similar to the mandibular first premolar. Where multiple lingual cusps are present, the mesial is usually larger and higher than the distal cusp. Variations can exist: for example, in the case of three lingual cusps, the occlusal surface is wider lingually in the mesio-distal direction than buccally; another variation is a second premolar compressed bucco-lingually.

The mesial surface of the crown is much more extensive and has less lingual convergence than the first premolar. The mesial contact area is located towards the buccal, at the junction of the occlusal and middle thirds. It is larger in size than the mesial contact of the first premolar. It is also roughly circular in outline. The mesial surface, although convex, is slightly flatter than the distal; however, similarly, the distal surface is
more extensive and has less lingual convergence than the first premolar. The distal contact area is similarly located to the mesial surface but, because it is shared with the first molar, it is larger and somewhat ovoid, wider bucco-lingually than occluso-cervically.

2.8 Mandibular first molar (Fig 2.2d) - when viewed from the occlusal aspect, the tooth has a convex buccal border on which there are two buccal grooves. This border rounds off onto a fairly straight mesial border and a convex distal border. The slightly convex or even straight lingual border is much shorter and less indented by a single lingual groove than the buccal border. A long and usually tortuous mesio-distal fissure separates the three buccal cusps from the two lingual cusps. At its mesial extremity, this fissure often bifurcates into two grooves or fissures, one passing buccally between the mesio-buccal cusp and the mesial marginal ridge, and the other lingually between the mesio-lingual cusp and the mesial marginal ridge. Often minor grooves pass from these two grooves over the marginal ridge.

The mesial surface of the crown flares out from the neck and is convex where it rounds off at the sides onto the buccal, lingual and occlusal surfaces. Near the neck and centrally, there is a flat area which flares mesially from the neck. The lingual border of the mesial surface
is erect and evenly convex, while the buccal border is convex near the neck but slopes lingually corresponding to the lingual inroll of the buccal surface. The contact area is round to slightly ovoid in shape, and is located slightly to the buccal at the middle and occlusal third junction.

When considering interproximal reduction where teeth will be reproximated, it is important to emphasise the need to preserve the nature and integrity of the contact area and its associated embrasure space. According to Fuller and Denehy (1984):

1. Contact areas increase in size with age. This broadening is due to the abrasion which occurs when the proximal surfaces of the teeth rub against each other. As a result, the mesio-distal length of the dental arches continuously becomes shorter;

2. The proper location of contact areas aids in stabilising the dental arch;

3. Proper contact areas also serve to prevent food material from slipping between the teeth. The chronic packing of food, if it occurs, usually results in an inflammation of the supporting soft tissues, which in turn may lead to a break down of the bony component of the periodontium. Thus, the replacement of a proper contact area in dental rehabilitation is of extreme importance;
4. Not only must the contact area be tight to prevent food packing, but its proper location, both in an occluso-cervical direction and a bucco-lingual direction, is also important in the food flow pattern;

5. In general, contact areas become more cervically located from anterior to posterior in each quadrant;

- on an individual tooth, the distal contact area normally has a slightly more cervical location than the mesial contact area;

- the relative size of the contact areas increases from anterior to posterior in each quadrant;

- posterior teeth have contact areas which are normally located to the buccal of centre in the bucco-lingual direction.

With regard to embrasure space (the open space between the proximal surfaces of two adjacent teeth in the same arch, where they diverge buccally or lingually, and occlusally or cervically from the contact area), Fuller and Denehy (1984) state that if an imaginary line is drawn to bisect any embrasure space, each half should be symmetrical so that the health of the periodontium is not jeopardised. This is because proper embrasure form has the physiological role of serving to protect the periodontium by acting as a spillway for the food material during mastication. They also describe a general inter-relationship which exists between contact areas and
embrasure form: "As the contact area becomes more cervically located the farther posteriorly in the arch, the relative size of the occlusal embrasure increases, while the relative size of the cervical embrasure decreases. And, as the contact area moves farther to the buccal in the posterior teeth, the lingual embrasure becomes relatively larger."
CHAPTER 3. THE STRUCTURE OF ENAMEL

Human dental enamel is a highly mineralized hard tissue of ectodermal origin. It consists of 96% mineral (densely packed hydroxyapatite crystals), 4% organic material (principally proteinaceous materials containing some polysaccharides) and water (Verbeeck, 1986). In the human tooth the enamel normally forms a layer over the entire crown varying in thickness from 2.5 mm at the incisive edge and cusps down to a fine edge at the cervical margin of the tooth (Scott and Symons, 1983). The high mineral content of enamel makes it extremely hard but brittle and gives it the ability, when supported by an underlying layer of resilient dentine, to withstand occlusal forces during function (Eisenmann, 1985).

Inorganic mature human enamel is generally accepted as being an apatite with a Calcium:Phosphate ratio slightly lower than hydroxyapatite Ca10(PO4)6(OH)2 with an approximate composition of: Ca, 37%; Na, 0.5%; Mg, 0.5%; PO4, 55.5%; CO3, 3.5%; water of constitution and traces of other ions; e.g. strontium, lead and fluoride (Brudevold and Soremark, 1967; Eisenmann, 1985; Verbeeck, 1986). These authors also point out that the percentage of inorganic and organic material is generally expressed in terms of weight and as such an incorrect impression of the true volumes may be given (inorganic material is
approximately one third the weight of mineral material v:v). They also report that 86% of the volume of fresh enamel is inorganic, 2% organic and 12% water. The water is said to form both a firmly bound hydration shell around the enamel crystallites and a loosely bound fraction between the enamel crystallites. The loosely bound fraction is freely mobile and readily exchanged. Between the crystallites and their hydration shell there is also a layer of adsorbed ions.

Scanning electron micrographs of mature human enamel show a fine lacey network of organic material between densely packed crystallites (Eisenmann, 1985). The chemical nature of this material is largely proteinaceous and contains some polysaccharide material. The configuration of the proteins in this organic component, known as enamolins, is not fully understood (Osborne and Ten Cate, 1976) even though the proportions of the constituent amino acids that give enamel a unique amino acid ratio are well known, i.e. histidine, lysine and arginine 3:1:1 compared to the eukeratins 1:4:12 (Osborne and Ten Cate, 1976). A very small amount of cystine, approximately one fourth the amount in keratin, and a high proportion of proline, further distinguish it from the keratins. Moreover, during maturation the maturing enamel matrix not only has progressively less protein but even the composition of this protein changes. This along with the
very small amounts available for sampling, and the possible contamination from adjacent dentine, has prevented the precise elucidation of the nature of the proteinaceous material, as was predicted by Stack (1967) and still referred to by Scott and Symons (1983).

However, what is known of enamolins is that: they are tightly bound to the apatite crystal surface and can only be extracted from enamel after the dissolution of the mineral crystals (Lyaruu, 1986); they occupy with water all existing space between crystals and structural analysis indicates some form of molecular orientation (Eisenmann, 1985); and current morphological and biochemical data indicates that in developing enamel they are involved in the orientation and regulation of crystal size (Lyaruu, 1986).

The ultrastructure of enamel shows it to be essentially a tightly packed mass of apatite crystals embedded in an organic matrix and arranged in cylindrically shaped rods. A repeating pattern of the hydroxyapatite molecules or unit cells builds up the so-called lattice structure of the crystallites. This lattice structure can be subject to ionic substitution (e.g. isoionic substitution of calcium for calcium or heteroionic replacement of calcium by magnesium). This changes the properties of the original hydroxyapatite, a further example of which is
the substitution of the fluoride ion for a hydroxyl ion in the lattice structure to produce the less soluble fluroapatite (Ogaard and Rolla, 1986). Whitlokite and possibly octacalcium phosphate have also been found to be present in some large crystals in surface enamel (Palamara et al., 1980). Crystallite shape has been varyingly described as slightly flattened hexagonal rods of generally fairly uniform size – width 40 nm, thickness 25 nm and length varying from 160 nm to 1 um (Silverstone, 1983). Crystallite shape has also been described as: lath shaped irregular hexagons – 50 to 100 nm wide and up to 1 um long (Johansen, 1964), long and lath like (Meckel et al., 1965) or hexagonal long rods with highly irregular cross-sections (Nylen, 1967).

Most of the structural features of enamel can be explained by its crystal orientation (Meckel et al., 1965). However, by being crystalline it is subject to optical interference when observed under the light microscope. As a result of this many misinterpretations of the true nature of enamel have been made. Perhaps the most confusing is the term enamel prism used by so many of the early workers (Poole and Brook, 1961; Glas, 1962; Meckel et al., 1965; Hardwick et al., 1965; Nylen, 1967; Helmcke, 1967). They used this term in an attempt to describe the observed structures but as there is no regular geometry for the basic unit, or resemblance to a
prism, the term enamel rod is more appropriate (Eisenmann, 1985). On average enamel rods are approximately 5 μm in width but show considerable variation throughout the enamel. Enamel rods are not present at either the inner or outer enamel surface, nor are they present in the gingival third of permanent teeth (Eisenmann, 1985).

The shape of enamel rods has been varyingly described. Lester (1964) like Hardwick et al. (1965) describes enamel rods as varying from square hexagonal or round through to arcade shaped or arcade/horseshoe shaped rods with interrod material flowing out to form a tail. Meckel et al. (1965) state that the keyhole is the most frequently observed shape. Long, irregular half cylinders with a narrow fin, the inter-rod substance extending from the flat surface is how Glas and Nylen (1965) describe the cross-sectional enamel rod shape. Swancar et al. (1970) state that the arcade-shaped rod is the most workable concept of an enamel rod structure and point out that the cross-sectional angulation of the observed section influences the appearance of the enamel rod.

The cross-sectional appearance of the rods and their rod sheaths may often give the appearance of an arcade or keyhole shape (Fig 3.1). However, it does not hold true for all enamel and as such the basic unit is best
Fig 3.1. Microstructure of enamel

Diagrammatic representation of the keyhole configuration of the enamel rods (ER) and enamel rod sheaths (RS) in human enamel. The head (H) of each enamel rod is orientated occlusally, whereas its tail (T) is orientated cervically. The crystallites generally run parallel to the head of the enamel rod but are bent downward in the tail of the prism and thus have a more oblong configuration when observed in cross section.

(from Renner, R.R., 1985. pp 138)
described as a cylindrically shaped rod that has a special relationship to the interrod region directly cervical to it (Eisenmann, 1985).

The orientation of crystallites within the enamel rod varies. Meckel et al. (1965) describe the crystallite orientation for their keyhole model as being parallel to the long axis in the front or occlusal section. Within the tail section the crystallites assume a near perpendicular arrangement to the enamel rod axis and fan out from the rod midline. This arrangement is in agreement with other authors of the time (Glas and Nylen, 1965; Hardwick et al., 1965). Eisenmann (1985) describes the crystal orientation for the majority of the enamel rods as having their long axes arranged parallel to the long axis of the rod with the exception of the peripheral crystals. These flare laterally to increasing degrees as they approach the boundary of the enamel rod and at the interrod region lie nearly perpendicular to the rod. Enamel rod sheaths are formed along the interface between groups of crystals with markedly different angulations. Oram (1966) when investigating this found no continuous structure that could be described as a distinct sheath. These regions, however, contain more protein than other regions of the crystals, presumably because of the different angles at which the crystals meet and hence the greater intercrystalline space that is available for
organic accumulation.

The normal surface morphology and topography of human enamel is characterised by several formations (Boyd, 1976; Fejerskov and Thylstrup, 1979). The perikymata pattern, small horizontal shallow furrows which appear on the surface as a result of the rhythmic manner in which enamel is formed, are considered to be where the striae of Retzius meet the surface (Gustafson and Gustafson, 1967). Newman and Poole (1974) in their investigation of surface enamel reported considerable variation in the perikymata both from region to region and also within the same region in respect of spacing, amplitude and size. Lamellae or cracks also often appear on the tooth surface as jagged lines. They are mainly found in the cervical half of the crowns and are more numerous on the interstitial surfaces than on the buccal or lingual surfaces (Gustafson and Gustafson, 1967). Some common developmental abnormalities such as Tomes' process pits, focal holes and overlapping projections have also been reported (Boyd, 1976). It is thus generally accepted that at this level of examination, the enamel surface profile displays large variations, not only between individuals but also from tooth to tooth as well as within small areas of the same tooth (Arends et al., 1983). This surface enamel, estimated to be approximately 30 um thick (Gwinnett, 1966), is also highly radio-opaque, harder and
less soluble than subsurface enamel. It may also contain
five to ten times more fluoride than subsurface enamel
(Weatherall et al., 1974). The crystallite orientation
also differs in this outer enamel in that the usual
enamel rod structure is missing and the crystallites are
smaller and lie with their long axis at right angles to
the enamel surface (Nylen, 1967; Newman and Poole, 1974).
This surface structure is affected by age and, in erupted
teeth, the subsurface layer forms the enamel surface with
the surface layer of fine crystallites lost by abrasion,
attrition and erosion (Eisenmann, 1985).

With age, enamel becomes less permeable. This is because
the crystals acquire more ions, increase in size and
decrease their pore space. As the bulk of water lies in
the pore space, the water content of enamel also
decreases with age. The surface layer of enamel also
changes with age as ionic exchange occurs within the oral
environment (Woltgens, 1986). This is particularly so for
fluoride, which can be shown to selectively increase in
the surface enamel independent of the mode of
application, be it by topical applications, water
fluoridation or dentifrice application (Groeneveld,
1986). Superimposed on the anatomical variations are
post-eruptive surface modifications due to a variety of
insults from the oral environment. Functional wear and
dental caries are among the most prominent insults and
even after only a relatively short period in the oral cavity considerable changes to the chemical composition and original surface morphology can occur (Arends et al., 1983).

Considerable research has been undertaken by numerous workers on the pattern of chemical variation within enamel (Arends et al., 1980; Verbeeck, 1986). In most instances individual tooth enamel sections are dissected and the subsequent analysis of those samples has enabled distribution maps (Robinson et al., 1983) or general gradient graphs (Verbeeck, 1986) of the chemical composition to be constructed. While generalisations are given, this work is acknowledged to be subject to complications brought about by the heterogeneity of the material. Human enamel differs from person to person, from tooth to tooth, is different for various tooth areas and strongly depends on food habits, oral hygiene etc. This heterogeneity is obvious at all levels from the interrod area (Wirsing, 1974) to the crystallites (Arends and Jongebloed, 1979) and presumably variations at the nanometer level exist because various ions may be in or on the crystal lattice structure (Arends et al., 1980).

Robinson et al. (1983) found that the pattern of calcium and phosphate distribution in general tended to decrease towards the enamel-dentine junction, although this
gradient varied considerably and was rarely uniform. The calcium:phosphate ratios were found to be reasonably constant throughout the tissues and consistent with a calcium deficient apatite. However at the surface somewhat lower calcium:phosphate ratios exist, perhaps as a result of interactions with the oral environment. A rough inverse correlation between the protein distribution pattern and the calcium:phosphate ratio is also found indicating that the mineral content decreases slightly with depth. Verbeek (1986), while pointing out the considerable heterogeneity of elemental distribution summarised the general concentration variations for magnesium, sodium, carbonate and chloride (Fig 3.2) and reported that no definite gradient is evident for potassium. These results are irrespective of the eruption status of the tooth. Density variations have also been recorded (Weatherell et al., 1967) and these patterns coincide with the patterns for carbonate and magnesium content. Magnesium has also been detected to be more concentrated along the striae of Retzius (Verbeek, 1986).

Trace elements in human dental enamel are seldom evenly distributed (Verbeek, 1986). Lead, zinc, manganese, copper and to a lesser extent silver, aluminium, iron, cadmium, tin, strontium and nickel occur in greater concentrations in the outer enamel layers than in the inner enamel layers. Although the absolute concentration
Fig 3.2. Qualitative form of the gradients for the content of CO₃, Na, Mg, Cl, and F as a function of depth in human tooth enamel between the tooth surface and the dentino-enamel junction. (from Driessens, 1986)
levels may vary considerably, the distribution profile in the enamel from different geographical areas remains qualitatively the same independent of the age of the tooth.

Verbeek (1986) when reviewing the distribution of fluoride concentrations stated that when going from the tooth surface to the dentino-enamel junction it showed a pronounced maximum in the outermost enamel (approximately 5 um and typical percentage value of 0.4% for water fluoridated teeth - Sampson et al., 1987), followed by a steep hyperbolic-like decrease towards a relatively constant value which is reached at depths of approximately 50 - 100 um. The fluoride concentration often rises again adjacent to the dentino-enamel junction. He reports that considerable differences are found in the absolute concentration as well as the steepness of the concentration gradient and that this varies from site to site even on the same tooth. The differences are mainly caused by the variations in the outermost layers and the distribution profile is affected by fluoride levels in the diet, age and specific tooth development aspects. In addition, wear, caused by attrition, and chemical erosion contributes to the variation in the fluoride gradient.
Enamel reduction of a tooth is easily accomplished using high speed, high torque dental handpieces and the appropriate cutting burs.

While the effects of cavity preparation on a tooth are well documented in numerous texts (e.g., Brannstrom, 1981), the effect on the pulp of cutting enamel only, for the purpose of remodelling teeth, has had little investigation. Zachrisson and Mjor (1975), using premolar teeth that were to be extracted for orthodontic purposes, found that there were no histological changes observed in the pulp of teeth that had undergone enamel grinding (providing that the enamel grinding was carefully done using abundant water cooling). This view on the effect on the pulp of grinding enamel is still accepted by the author (Zachrisson, 1987). However, he points out that damage to the pulp can occur if the surfaces have been notched and are not readily cleansable. This pulpal inflammation, which he attributes to notching, is brought about by plaque retention and hence damage to the enamel and subjacent dentinal tubules, resulting in the minor pulpal irritation (odontoblast nuclei displaced into dentinal tubules, increased number of blood vessels, distinct cell-free zone not discernible, slight infiltration of inflammatory cells).
Sheridan (1985) states that there are no studies that indicate how much enamel is needed for adequate protection of the tooth against carious, thermal or chemical damage. He further suggests that the natural variations in the thickness of enamel over the tooth surfaces (e.g. comparatively thin enamel occurs on parts of the labial, buccal and lingual surfaces) indicate that there is no protective advantage of preserving thick enamel interproximally. It is known that ground enamel, if exposed to the oral environment, will acquire the same properties as normal surface enamel (van der Fehr and Steiness, 1966). Presumably this is due to the ionic exchange that occurs within the oral environment (Woltgens, 1986). From the above it may therefore be concluded that the grinding of enamel, leaving readily cleansable enamel surfaces exposed, is not harmful to the teeth.
CHAPTER 5. THE AMOUNT OF ENAMEL WHICH CAN BE REMOVED

A general consensus exists amongst authors that only half the enamel thickness should be removed when stripping interproximally (DiPaolo and Boruchov, 1971; Peck and Peck, 1975; Reidel, 1975; 1976; Zachrisson, 1978; Betteridge, 1979; Tuverson, 1980; Boese, 1980; Joondeph and Reidel, 1985 and Camilla Tulloch, 1986). If further trimming is to be undertaken, it is thought by some authors that discolouration, increased sensitivity to thermal changes and a predisposition to decay may be produced (Reidel, 1976 and Boese, 1980). If this arbitrary value is to be accepted, proximal stripping is limited to the thickness of the enamel on each tooth at its contact point. This enamel thickness is known to vary between individual teeth and even individual tooth surfaces and hence a means of assessing this thickness needs to be available. An easy way to assess this thickness is to use X-rays, as suggested by DiPaolo and Boruchov (1971), Goldman and Cohen (1980), Sheridan (1985) and Joondeph and Reidel (1985). Sheridan (1985) uses bitewing X-rays and believes that the thickness of the interproximal enamel can be estimated by projecting a line vertically from the cervical line of the tooth to the occlusal or incisal plane. Dentine is projected in a straight line from the cervical line or a line that tapers slightly towards the pulp (Fig 5.1). Using this
Fig 5.1. An X-ray showing dentine tapering from the cervical line towards the pulp.
(from Sheridan, 1985)
procedure and accepting the average values for mesio-distal width of the crown and neck of individual teeth as given in Gabriel (1965), the average enamel width for posterior teeth can be calculated. This is shown in Table 5.1, where an amount of 0.5 mm per tooth surface can be seen as a justifiable amount of enamel to remove. It should be noted, however, that the values in Table 5.1 are averages only and additional care in assessment needs to be given to maxillary second premolars and maxillary canines. Sheridan (1985) cites Shillinbourg and Grace measurements and states that a 0.3 mm reduction per tooth surface is possible. However, it should be appreciated that, as larger amounts of enamel are removed, the risk of inadvertently involving dentine is also increased. It is for this reason that an amount of 0.5 mm will be advocated as optimum for interproximal reduction purposes.
Table 5.1. Approximate combined mesial and distal enamel thickness.

<table>
<thead>
<tr>
<th></th>
<th>Crown width (mm)</th>
<th>Neck width (mm)</th>
<th>Enamel thickness (approx) (combined mesial and distal - mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuspid</td>
<td>6.9</td>
<td>5.2</td>
<td>1.7</td>
</tr>
<tr>
<td>1st Premolar</td>
<td>6.9</td>
<td>4.7</td>
<td>2.2</td>
</tr>
<tr>
<td>2nd Premolar</td>
<td>7.1</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Molar</td>
<td>11.2</td>
<td>8.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuspid</td>
<td>7.6</td>
<td>5.2</td>
<td>2.4</td>
</tr>
<tr>
<td>1st Premolar</td>
<td>7.2</td>
<td>4.9</td>
<td>2.3</td>
</tr>
<tr>
<td>2nd Premolar</td>
<td>6.8</td>
<td>5.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Molar</td>
<td>10.7</td>
<td>7.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

(from Gabriel, 1965)
CHAPTER 6. THE EFFECT OF FLUORIDE ON THE ALTERED TOOTH SURFACE

Interproximal reduction requires the removal of a part of the outer enamel surface of the tooth. This new outer surface may be sound enamel, differing slightly in composition, as discussed in the structure of enamel (Chapter 3). This sound enamel surface will take up fluoride if the fluoride is applied topically (Ogaard and Rolla, 1986), and retain considerable amounts of it in the form of calcium fluoride. This outer surface may also end in part of a subsurface lesion which is probably not clinically detectable since early subsurface demineralisation is not apparent in bitewing radiographs (Kidd, 1986). Such a subsurface lesion can, if recognised, be remineralised by saliva alone, providing it is kept clear of bacterial plaque. However, the presence of fluoride increases this remineralisation (Ten Cate, 1983). Kouluorides and Housch (1983) found that any presoftening of enamel (early carious attack) also favoured higher fluoride incorporation and hence increased resistance to further acid attack. In a more recent study, Featherstone et al. (1986) found that enhanced remineralisation was dependent on the fluoride concentration. Their studies also supported the concept of frequent (daily) applications of low concentrations of fluoride, and even in situations of high caries
challenge, fluoride can effectively inhibit demineralisation and enhance remineralisation.

In summary, it can be inferred that frequent plaque removal and local availability of fluoride in the altered interproximal area will tend to arrest any early cariogenic process if present, and convert the area of susceptibility to an area of resistance. However, if plaque cannot be removed (due to a rough or notched surface), it is unlikely that fluoride will have the same effect (Zachrisson, 1987).
CHAPTER 7. PERIODONTAL CONSIDERATIONS

The long-term effect of orthodontic treatment on the periodontium has been investigated (Sadowsky and BeGole, 1981; Kennedy et al., 1983; Polson and Reed, 1984), but no difference in the level of periodontal attachment between treated and untreated persons or differences in the level of crestal bone between study and control groups have been found. However, Pritchard (1975), Hatasaka (1976) and Kessler (1976) suggest that malposed or rotated teeth may predispose to a more rapid breakdown of the periodontium. This is because they believe that an adequate space between the teeth at the level of the crestal bone is necessary for continued gingival health, particularly where roots are in close proximity and result in a thin interproximal bony septum. This interpretation has resulted in a general belief that inherent dangers exist in interproximal reduction whereby orthodontic reproximation could reduce the amount of trans-septal bone between teeth and predispose these areas to periodontal disease (Klassman and Zucker, 1969; Hatasaka, 1976; Boese, 1980). However, until recently (Artun et al., 1986; 1987), no one has tried to correlate long term periodontal health and tissue destruction with the thickness and configuration of the alveolar bone. These authors found that for anterior teeth "no statistically significant differences in inflammation,
levels of attachment, and bone level were observed between root proximity sites and control sites and conclude that anterior teeth are not predisposed to more rapid periodontal breakdown when tooth roots are in close proximity. To date, there are no long-term studies that have looked at the effects of root proximity and periodontal health in posterior teeth. In the Artun et al. (1986, 1987) study of 400 patients only two posterior root proximity sites were recorded and these authors state that a larger sample is necessary to confirm or disprove the findings for anterior teeth, particularly in view of the fact that the bony architecture, crown form, root morphology and shape of interproximal contact are different between anterior and posterior teeth. Pritchard (1975) and Hatalska (1976) also state that a difficulty in curetting the root surface in molars may result in a poor prognosis when periodontitis is involved. However Nyman et al. (1984) using dogs as an experimental model found, in a short-term study (six months), that the presence of bone does not imply an increased resistance to the progression of periodontal disease. This tends to support the hypothesis that a thin bony septum alone, resulting from roots being brought closer together by reproximation, does not predispose a patient to an increased risk of periodontal disease.
CHAPTER 8.  INDICATIONS, PRECAUTIONS AND CONTRAINDICATIONS FOR INTERPROXIMAL REDUCTION IN POSTERIOR TEETH.

8.1. Indications for reproximation in posterior teeth

Sheridan (1985) states that air-rotor stripping enables the clinician to remove a precise amount of interproximal enamel and create space, primarily in the buccal quadrants, for aligning and retracting teeth. He further states that this interproximal reduction can be carried out at any time during treatment without discomfort to the patient and without adversely affecting the function of the dentition, tooth form or interocclusal relations. This technique, he believes, has the ability to resolve significant differences in the ratio of tooth size to arch size, and can possibly become an alternative to extraction or expansion. Lyngoy (1987) lists a number of instances where interproximal reduction is indicated:

(i) Late crowding, especially that seen in young adult or more mature dentitions where slight to moderate crowding may be resolved by reproximation instead of extraction of teeth. This is particularly indicated where there are proximally overcontoured restorations in the posterior teeth. However, consideration of the intercuspal relationship must be given when single arch interproximal
reduction is undertaken.

(ii) Where there are unstable contact points, especially when rotated teeth have been corrected, moderate interproximal reduction may be indicated to lock the teeth in position and lessen the potential for rotational relapse.

(iii) Moderate midline deviations in adult patients may be corrected by a limited reproximation in one quadrant of the upper arch and the diametrically opposed quadrant of the lower arch. This has the advantage of creating a more favourable overjet and overbite than that which is obtained in single arch interproximal reduction.

(iv) Lyngoy believes that extraction of maxillary first premolars and mandibular second premolars creates a tooth-size discrepancy between the arches with the mandibular first premolar being wider mesiodistally than the maxillary second premolar. Here a moderate interproximal reduction in the maxillary molar/premolar region will give a better interdigitation of the cusps and better function. However, this mesiodistal tooth size discrepancy he cites is not in agreement with the values given by Gabriel (1965), which agrees with the tooth size data of Bolton (1958), and shows no difference between the average mesiodistal widths of these particular teeth,
but does concur with one of two groups studied by Doris et al. (1981). This point, however, highlights the need to look at the individual tooth-size in any differential extraction case.

(v) Missing maxillary incisors, in arches which are compensated for by moving the canines into that position, often require interproximal reduction in the mandibular arch to improve the occlusion and avoid the mesiopalatal rotation of the maxillary first molar.

(vi) Crowding of anterior teeth involving an arch-length discrepancy of less than 5-6 mm, in cases with class 1 molar and canine relationships and where the extraction of a mandibular incisor may otherwise be indicated, are suitable cases for interproximal reduction. This is because it is necessary to aesthetically reshape the remaining lower incisors (Zachrisson, 1987) to avoid "black triangles", and as a result an arch length discrepancy would otherwise exist.

(vii) Where crown morphology is favourable and there is a minor to moderate tooth-size discrepancy (Bolton discrepancy - Bolton, 1962), may be corrected for by interproximal reduction. However, as Lombardi (1975) found (in a survey of thirty treated cases), the anterior Bolton ratio could not be correlated with mandibular
incisor crowding; however, he did find that a moderate positive correlation between the mandibular coefficient of crowding (ratio of tooth material to arch length discrepancy) and total width of all mandibular teeth existed. This supports Sheridan's (1985) observation that occasionally opposing arches may need interproximal reduction to improve intercuspation irrespective of their Bolton discrepancy.

Robert Williams (1986) counsels against the extraction of mandibular second premolars because the flat distal surface of the second premolar against the first molar is better than the first premolar against the first molar. Zachrisson (1987) describes the advantages of posterior interproximal reduction as:

(i) In slight crowding cases the need for extraction is eliminated.

(ii) There is less bone loss — in respect of bone height — compared to extraction cases.

(iii) A more stable result is obtained by broadening the contact areas.

(iv) Modifications of individual variations in tooth size and shape are possible.
(v) A more favourable overbite and overjet can be achieved in some cases and so improve anterior function in the mutually protected occlusion.

(vi) Areas of interproximal gingival recession may be improved although the tooth morphology in the gingival region needs to be considered in such cases.

8.2. Precautions to be considered when reproximating posterior teeth.

Zachrisson (1987), like other workers (Boese, 1980; Sheridan, 1985; Lyngoy, 1987), states that reproximation is not without risks, namely:

(i) Impaired function and aesthetics resulting from careless reduction.

(ii) Possibility of promoting caries.

(iii) The use of inadequate cooling may lead to overheating and pulpal damage.

(iv) Uncertain prognosis of cases with parallel roots - although most of this uncertainty has been dispelled by
the findings of Artun et al. (1986; 1987).

(v) An increased difficulty in scaling and flossing may increase the risk of periodontal disease. This concern is possibly brought about by the work of Ainamo (1972), who found no correlation between poor oral hygiene or very good oral hygiene and periodontal disease, but a positive correlation in average groups between an increase in malalignment and periodontal disease.

(vi) Hypersensitivity and pulpal damage as a result of over-zealous reduction. This may also result in a colour change if pulpal irritation is sufficient to cause extensive secondary dentine deposits, or even a loss of vitality.

(vii) There is a need to avoid placing the reproximated contact area subgingivally and ideally this should be placed so that it is approximately 1 mm from the gingival papilla. If not, the reduced space for the interproximal papilla causes the gingival tissue to be evicted from between the adjacent teeth, creating an oversized col - such as occurs with an overcontoured crown (Takei, 1980; Becker and Kaldahl, 1981). The long-term effect of this is to cause a deepening of the interproximal col (a non-keratinised area which is thought to be more susceptible to plaque - Hagen and Osborne, 1967) which then becomes
difficult to clean and results in plaque retention causing periodontal disease and possible pocket formation. This defect can then only be repaired by either lowering the general level of the gingiva or reshaping the teeth to provide an acceptable space (Goldman and Cohen, 1980).

(viii) As first mentioned by DiPaolo and Boruchov (1971), teeth with approximal hypoplasia and hypocalcification should be treated cautiously when stripping interproximally. This is because these teeth may be more susceptible to iatrogenic dentine involvement making them sensitive or susceptible to caries activity.

(ix) Soft tissue lacerations - particularly resulting from the use of large rigid discs within the oral cavity.

8.3. Contraindications for reproximation in posterior teeth

Lyngoy (1987) and Zachrisson (1987) are both in agreement with the following contraindications:

(i) Where the total amount of dental enamel to be removed is in excess of what is clinically accepted, in order to result in tooth size/arch coordination (Sheridan, 1985,
states that a cumulative gain of approximately 9 mm within one side of an arch is feasible, 6.4 mm of this being attributed to the eight buccal contacts - including second molar teeth).

(ii) In cases of poor oral hygiene which fail to respond to instruction.

(iii) In cases of high caries activity.

(iv) Where there is tooth deformity resulting in parallel interproximal surfaces and any reduction in tooth structure would either lower the contact area or cause root damage.

(v) In systemic conditions that result in gingival hyperplasia or hypertrophy such that interproximal access is most difficult (e.g. dilantin hyperplasia).
CHAPTER 9. METHODS AND MATERIALS

9.1. Teeth for investigation of interproximal and marginal ridge morphology

To develop the form and length of a high speed dental bur suitable for maintaining a marginal ridge form, it is first necessary to determine the dimensions of the marginal ridge and the proximal surface.

Teeth for this investigation were obtained from the Dental Health Education and Research Foundation Tooth Repository, held at Westmead Hospital Dental Clinical School, under the care of Associate Professor B.R.D. Gillings. Typical samples of each tooth type to be investigated, namely maxillary canines, first premolars, second premolars and first molars, and the corresponding mandibular canines, premolars and molars were obtained. Only sound specimens were obtained. All teeth were within the range for mesio-distal width as described by Gabriel (1965). No distinction between left and right was made. The teeth were orientated for vertical crown angulation and a pencil line was drawn down the buccal surface of the teeth parallel to the vertical. The mesial surface of each tooth was marked by placing a small groove (for orientation purposes) just above the cemento-enamel junction. The root of the tooth was then part-sectioned
from the buccal approximately 2 mm from the buccal cemento-enamel junction at right angles to the long axis of the crown. The tooth was then secured in a vice and sectioned mesiodistally, at a point corresponding to the contact area, using a Superdiaflex diamond disc (Horico-537/220H- Hopf Ringleb and Co. GmbH, Berlin). A second slice, using the same orientation, was then made from the secured tooth such that a section of tooth approximately 0.75 mm wide could be removed for examination. This section of tooth structure was then placed on a glass projection slide, along with a short section of 1 mm wire. Both were attached to the glass projection slide with cyano-acrylate adhesive. The slide of each sample (n = 10) for each tooth type was placed in a projector and projected onto grid paper so that a 20x magnification resulted (Fig 9.1). Each of the tooth samples described in the results was produced in this way. The image of the tooth was kept as vertical as possible by using the sectioned base of the tooth as a reference and the mesial surface was identified by the fine groove. Once projected onto the grid, fine line diagrams were made of the outline of the projected image (Fig 9.2).

9.2. Preparation of tungsten carbide burs for interproximal reduction

The instruments required to make the finishing burs are:
Fig 9.1. Mesio-distal section of a tooth secured on a projection slide.

A groove on the mesial surface of the tooth for orientation purposes is shown along with a section of 1.0 mm diameter wire to verify magnification.
Fig 9.2. Experimental tooth section.

A line diagram outline obtained from the projected slide of a mesio-distal tooth section showing the vertical amount of tooth affected by 0.5 mm of tooth reduction (line x - y, distance a - c) and the approximate height from contact area (b) to position on marginal ridge brought about this 0.5 mm reduction (a) (line x - y, distance a - b).
an air-turbine handpiece, a diamond bur or stone, and an appropriate tungsten carbide bur (PG HM 49 XL/014 or PG HM 50/018, Meisinger, Hager and Meisinger, GmbH, Dusseldorf, West Germany) as shown in Fig 9.3. It is important that the air-turbine handpiece should run concentrically; the bur to be changed to an interproximal separating bur should be placed in the handpiece and run with the cooling spray. The blades of the commercially available bur are ground away by holding a diamond at right-angles to the bur. The particular shape is created by using the diamond as a lathe tool (Fig 9.4). Depending upon the grade of diamond used against the bur, so will depend the speed of the reduction and the size of the scratches which are produced by the diamond particles. Shallower scratches are also left if a lighter load is used towards the end of the milling operation. The abrasive action of the custom finishing burs prepared in this way results from the very fine tungsten carbide particles exposed on the surface. These particles could be expected to produce scratches on the tooth, but they are very small, relative to the scratches left by a diamond bur, and unlikely to be of any clinical significance. After shaping, the burs are then sandblasted to produce the final surface finish. This sandblasting has the effect of reducing some of the scratches left by the diamond.
Fig 9.3. Tungsten carbide burs used for preparation of customised tungsten carbide bur (Meisinger HM 49 XL/014, left; Meisinger HM 50/018 right).

Fig 9.4. Preparation of customised tungsten carbide bur.
9.3. Using the tungsten carbide finishing burs

A suitable compromise between speed and accuracy of cutting is achieved with speeds of between 300,000 and 400,000 r.p.m. (Baker and Curson, 1974). Slower speeds require a longer period of time and encourage heavier loads on the bur. Under such conditions, it is difficult to achieve a smooth surface, as control over the bur is reduced. This reduced control increases the risk of damage to the tooth, by creating small ridges or grooves on the proximal surface. Although the use of water spray with the air-turbine handpiece reduces visibility, it is essential, because without it, overheating and smearing of the enamel will occur.

9.4. Teeth for use in enamel reduction experiments

To test the effect of cutting enamel using dental diamonds and the proposed dental carbide stones, premolar teeth were obtained from orthodontic patients at the United Dental Hospital of Sydney requiring extractions of these teeth. Immediately after extraction, the teeth were placed in distilled water. They were later debrided, replaced in distilled water and stored under refrigeration until preparation. The interproximal enamel surfaces were examined under a dissecting
microscope and the teeth with marred enamel surfaces were eliminated.

9.5. Enamel reduction experiments

The teeth obtained as described above were each subjected to enamel reduction corresponding to 0.5 mm on either the mesial or distal surfaces. Four types of reduction procedures were used.

i. Medium grit diamond (Iso Diamant, Cat. no. 884/011-3 - Iso Diamant Australia, Manly, NSW)

ii. Ultrafine finishing diamond, (Iso Diamant, Cat no.884/010-4 )

iii. Customised finishing bur

iv. Customised finishing bur followed by 3M XT polishing disc in abrasive grades: medium, fine, superfine. (3M Dental Products Division, Sydney, Australia).

The finishing discs are shown in Fig 9.5.

All tooth reduction was carried out using a high speed handpiece with copious water flow. The individual teeth were secured in a bench vice to allow for ease of preparation. The surfaces were prepared by moving the
Fig 9.5. Finishing discs.

Two sizes of 3M XT finishing discs (large and small) in three grades of abrasives - (from left to right) medium, fine and superfine are shown. Gradations on the left in millimeters.
burs laterally from the buccal to the lingual and vice-versa, to simulate what would occur in a clinical situation. With the two diamond burs no attempt was made to create marginal ridge form. However, marginal ridge form was created with the customised bur preparations and the customised bur preparations finished with the 3M polishing discs. These recently available discs are small and extra-fine and give good access with or without the arch wires being in position. After surface preparation, samples were then prepared for examination using the scanning electron microscope.

9.6. Preparation of the surfaces for scanning electron microscopy

After the teeth were adjusted using a variety of interproximal reduction aids, the specimens were then sectioned mid-way along the root of the tooth. They were then placed in an ultrasonic cleaner for five minutes in distilled water, taken out, air dried and placed in a desiccator for twenty four hours. The dried specimens were mounted on aluminium studs and covered with 20 nanometers of gold-palladium using a magnetron sputter coating process (custom-modified Dynavac coating unit, University of Sydney, Australia), calibrated with a filament thickness monitor. This thickness is necessary to ensure adequate secondary electron reduction. The
dried coated specimens were examined immediately in a Joel JSM 35C scanning electron microscope. Scanning electron micrographs were taken at standard magnifications for comparative purposes.

9.7. Clinical operating conditions for interproximal reduction

Patients should be supine, the operator seated and the interproximal reduction carried out by direct vision wherever possible. A higher standard of precision is more likely with direct rather than with indirect vision. The use of interproximal separating O modules (separators) causes the gingival tissue to be displaced somewhat from the area to be reduced. By using the very fine customised tungsten carbide bur, minimal damage is caused to the gingival tissue. This is probably because the tissue is displaced by the air and water and there are no sharp surfaces to grab or tear at it, such as occurs when a diamond is used. Also, the pressure with which the finishing bur touches the gingival tissue is usually not enough to cause noticeable damage from friction, abrasion or heat.
CHAPTER 10. RESULTS

10.1. Investigation of the mesiodistal morphology of posterior teeth

Interproximal reduction and subsequent orthodontic reproximation of posterior teeth, as described in Chapter one and popularised by Sheridan (1985; 1987), involves removing enamel from the interproximal surface of adjacent teeth. In order to determine what proportion of enamel could be removed and what shape the resultant enamel surface should take, a randomly selected sample (n = 10) of each posterior tooth type was obtained from the Dental Health Education and Research Foundation Tooth Repository. Each tooth was examined and found to be representative of the tooth type, and then sectioned as described in Methods. The results obtained also determined the shape and length of the customised bur being developed.

Table 10.1 and Table 10.2 show the results of a series of measurements taken to determine the amount of vertical tooth structure which has to be removed to allow for a reproximation of 0.5 mm per tooth surface, given that the tooth is in a normal relation with its adjacent neighbour. Each result given for a particular tooth surface is the mean of ten individual sections taken, as
Table 10.1. Vertical height of maxillary enamel to be removed to allow for a 0.5 mm interproximal reduction.

<table>
<thead>
<tr>
<th>Tooth Surface</th>
<th>Mean (mm)</th>
<th>SD (n-1)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C D</td>
<td>4.24</td>
<td>0.225</td>
<td>4</td>
</tr>
<tr>
<td>Pm 1 M</td>
<td>3.05</td>
<td>0.171</td>
<td>2.85</td>
</tr>
<tr>
<td>Pm 1 D</td>
<td>3.48</td>
<td>0.227</td>
<td>3.1</td>
</tr>
<tr>
<td>Pm 2 M</td>
<td>2.63</td>
<td>0.204</td>
<td>2.35</td>
</tr>
<tr>
<td>Pm 2 D</td>
<td>2.69</td>
<td>0.213</td>
<td>2.4</td>
</tr>
<tr>
<td>M 1 M</td>
<td>3.41</td>
<td>0.301</td>
<td>2.95</td>
</tr>
</tbody>
</table>

The vertical height of enamel that has to be removed in maxillary teeth to allow for a 0.5 mm mesio-distal reduction in tooth structure as described in Methods and Materials (Fig 9.2) is shown. The mesial (M) and distal (D) surface of canine (C), first premolar (Pm 1), second premolar (Pm 2) and first molar (M 1) measurements are described. (n = 10)
Table 10.2. Vertical height of mandibular enamel to be removed to allow for a 0.5 mm interproximal reduction.

<table>
<thead>
<tr>
<th>Tooth Surface</th>
<th>Mean (mm)</th>
<th>SD (n−1)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C  D</td>
<td>4.43</td>
<td>0.221</td>
<td>4.2 − 4.85</td>
</tr>
<tr>
<td>Pm 1 M</td>
<td>3.08</td>
<td>0.190</td>
<td>2.85 − 3.4</td>
</tr>
<tr>
<td>Pm 1 D</td>
<td>3.11</td>
<td>0.249</td>
<td>2.8 − 3.45</td>
</tr>
<tr>
<td>Pm 2 M</td>
<td>3.59</td>
<td>0.298</td>
<td>3.0 − 3.95</td>
</tr>
<tr>
<td>Pm 2 D</td>
<td>4.10</td>
<td>0.431</td>
<td>3.7 − 4.95</td>
</tr>
<tr>
<td>M 1 M</td>
<td>4.47</td>
<td>0.394</td>
<td>3.75 − 4.90</td>
</tr>
</tbody>
</table>

The vertical height of enamel that has to be removed in mandibular teeth to allow for a 0.5 mm mesio-distal reduction in tooth structure as described in Methods and Materials (Fig 9.2) is shown. The mesial (M) and distal (D) surface of canine (C), first premolar (Pm 1), second premolar (Pm 2) and first molar (M 1) measurements are described. (n = 10)
described in Methods, from individual teeth, for the length a to c on the line x-y in Fig 9.2.

For all teeth examined, the proposed 0.5 mm reduction would not encroach upon root form and would be a clinically acceptable amount of tooth structure to be removed.

In the maxilla (Table 10.1) the tooth surface that requires the greatest amount of vertical enamel to be removed, so that 0.5 mm of the proximal surface of the tooth can be removed, is the distal surface of the maxillary canine. This requires the removal of a mean amount of 4.24 mm of enamel, with a range, on the samples observed, of 4 mm to 4.8 mm. The mean vertical height of enamel that needs to be removed from the mesial and distal surfaces of the maxillary first premolar and the mesial surface of the maxillary first molar are similar but there is slightly less to be removed from the mesial and distal surfaces of the maxillary second premolar. The upper recording for the height of enamel that has to be removed approaches 4 mm for the mesial surface of the molar and slightly less for the first premolar. For the second premolar, a height of approximately 3 mm is required so that a 0.5 mm reduction on the mesial or distal proximal surface can be effected.
In the mandible (Table 10.2) the results for the distal surface of the canine show that, for a 0.5 mm reduction in mesio-distal width of the tooth, a similar reduction in height to the maxillary teeth is required (mean = 4.43 mm; range 4.2 - 4.85 mm). The actual height of enamel that has to be removed in the premolar region is also similar for the mesial and distal surfaces of the first premolar to that of the maxillary counterparts, but the height reduction requirement for the second premolar is reversed to that of the maxilla with a mean on the distal surface of the second premolar of 4.31 mm and the highest recording being 4.95 mm. This latter value for the second premolar is similar to that of the mesial surface of the first molar (4.9 mm), which has a mean value of 4.47 mm. These values are important because the reduction burs must be at least this long to be able to effectively reduce a tooth by 0.5 mm in width without creating any ledging or notching.

For any interproximal reduction and subsequent orthodontic reproximation, the height of the contact area also needs to be considered so that the teeth, when repositioned against each other, will have similar marginal ridge form.

To achieve orthodontic reproximation after interproximal reduction, with the teeth repositioned so that they have
a similar marginal ridge form to that of the pretreatment morphology, the height of the contact area needs to be considered. This is the distance measured from a to b on the line x-y in Fig 9.2. Table 10.3 shows that the height from the contact area to the marginal ridge in the maxillary teeth which needs to be retained with a 0.5 mm interproximal reduction is approximately 1.2 mm, with the first premolar having a slightly higher value than the molar and second premolar, but in general there is a similar height for these marginal ridge forms. The maxillary canine has no marginal ridge form and a mean value for this measurement is in excess of 2 mm.

Table 10.4 gives the values for the distance from the contact area to the new marginal ridge form brought about by a 0.5 mm interproximal reduction in mandibular teeth. As was found in the maxilla, the distal mandibular canine surface does not have a ridge form and the measurement from the contact area to the limit of the new reproximated surface is 2.5 mm. The remaining measurements for the mandibular marginal ridges are similar with 1.3 + 0.1 mm covering the mean values for the five surfaces.
Table 10.3. Distance from the contact area to the new marginal ridge form brought about by a 0.5 mm interproximal reduction in posterior maxillary teeth.

<table>
<thead>
<tr>
<th>Tooth Surface</th>
<th>Mean (mm)</th>
<th>SD (n-1)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C D</td>
<td>2.025</td>
<td>0.266</td>
<td>1.85 - 2.55</td>
</tr>
<tr>
<td>Pm 1 M</td>
<td>1.38</td>
<td>0.250</td>
<td>1.1 - 1.85</td>
</tr>
<tr>
<td>Pm 1 D</td>
<td>1.28</td>
<td>0.102</td>
<td>1.1 - 1.35</td>
</tr>
<tr>
<td>Pm 2 M</td>
<td>0.945</td>
<td>0.165</td>
<td>0.8 - 1.3</td>
</tr>
<tr>
<td>Pm 2 D</td>
<td>1.05</td>
<td>0.117</td>
<td>0.85 - 1.15</td>
</tr>
<tr>
<td>M 1 M</td>
<td>1.18</td>
<td>0.139</td>
<td>0.95 - 1.35</td>
</tr>
</tbody>
</table>

Height from the contact area to the new marginal ridge form brought about by a 0.5 mm interproximal reduction in posterior maxillary teeth is determined as described in Methods and Materials (Fig 9.2). The mesial (M) and distal (D) surface of canine (C), first premolar (Pm 1), second premolar (Pm 2) and first molar (M 1) measurements are described. (n = 10)
Table 10.4. Distance from the contact area to the new marginal ridge form brought about by a 0.5 mm interproximal reduction in posterior mandibular teeth.

<table>
<thead>
<tr>
<th>Tooth Surface</th>
<th>Mean (mm)</th>
<th>SD (n-1)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C  D</td>
<td>2.12</td>
<td>0.385</td>
<td>1.15 - 2.5</td>
</tr>
<tr>
<td>Pm 1 M</td>
<td>1.23</td>
<td>0.153</td>
<td>0.85 - 1.35</td>
</tr>
<tr>
<td>Pm 1 D</td>
<td>1.25</td>
<td>0.175</td>
<td>0.95 - 1.50</td>
</tr>
<tr>
<td>Pm 2 M</td>
<td>1.36</td>
<td>0.105</td>
<td>1.25 - 1.50</td>
</tr>
<tr>
<td>Pm 2 D</td>
<td>1.33</td>
<td>0.204</td>
<td>0.95 - 1.6</td>
</tr>
<tr>
<td>M 1 M</td>
<td>1.40</td>
<td>0.166</td>
<td>1.15 - 1.65</td>
</tr>
</tbody>
</table>

Height from the contact area to the new marginal ridge form brought about by a 0.5 mm interproximal reduction in posterior mandibular teeth is determined as described in Methods and Materials (Fig 9.2). The mesial (M) and distal (D) surface of canine (C), first premolar (Pm 1), second premolar (Pm 2) and first molar (M 1) measurements are described. (n = 10)
10.2. Determining the general shape for the interproximal reduction bur

Ideally, the interproximal reduction bur would have a specific shape for each marginal ridge form. However, this would not prove to be practical, since the aim is to remove both the mesial and distal marginal ridge of two adjacent teeth simultaneously, i.e. one interproximal area. In order to determine a general shape for this, the individual shapes of the ten samples were composed and made into an overlay with each superimposed upon the other. One general line which appeared to be a line of best fit and corresponded to the mean height of each sample (Table 10.3, Table 10.4) was made for each tooth ridge. The result of this is shown in Fig 10.1 (a and b). Here the average form for each mesial or distal ridge is shown in the one orientation for ease of comparison. By superimposing each upon the other individual units shown in Fig 10.1a and 10.1b, there appear to be two general types of marginal ridge form. One type for the surface of distal canines and another type for the proximal ridges of the premolars and mesial marginal ridges of the molars. When each of the individual composite forms for premolars and mesial surface of the molars in Fig 10.1a and Fig 10.1b is imposed upon the other, a general fit for the marginal ridge can be determined. This is shown in Fig 10.2. Fig 10.3 shows the shoulder shape of a bur
Fig 10.1. Height and contour of marginal ridges above the contact area effected by a 0.5 mm reduction in tooth structure.

Each line represents the composite average for mesial (M) and distal (D) height and contour of the marginal ridge above the contact area, obtained as described in Methods and Materials (Fig 9.2) for maxillary (a) and mandibular (b) posterior teeth \((n = 10)\). The canine (C), first premolar (Pm 1), second premolar (Pm 2) and first molar (M 1) height contours are shown.
Fig 10.2. Composite marginal ridge form.
A composite marginal ridge shape (X) is formed from average marginal ridge forms of premolar and molar teeth from Figs 10.1a and 10.1b.

Fig 10.3. Custom bur shape.
The shoulder form (X) is the same as the marginal ridge form in Fig 10.2. The shank(A) and parallel cutting surface(B) constitute the rest of the bur.
which conforms to this shape. It is this shape which is copied when preparing the bur described in Methods to give the general shape shown in the micrograph, Fig 10.4. Small marks from the diamond bur used to shape the customised bur are still evident but these are of no clinical significance.

A high-power micrograph (Fig 10.5) shows the nature of the tungsten carbide surface which is responsible for cutting tooth structure. However, if comparisons of Table 10.1 and Table 10.2 are made, it can be seen that the length of the bur required varies from tooth to tooth. This length can be determined by observing bite-wing radiographs (Sheridan, 1985) combined with a knowledge of the approximate levels required for each tooth form. In determining the length of the bur, the maximum values obtained in the samples studied should be used. This is because it is better to go beyond the length required for a tooth, rather than to foreshorten, as a possibility of notching the proximal surface exists if the bur is short. If the bur appears too long (observed after the first pass through the interproximal area) then the use of a shorter bur is appropriate. Many burs of various lengths can easily be produced or the bur may be simply shortened at the chairside by rotating it against a diamond surface.
Fig 10.4. Scanning electron micrograph of a customised tungsten carbide bur. (field width 6 mm)

Fig 10.5. High power scanning electron micrograph of customised tungsten bur. The area shown above is from the parallel cutting section of the bur shown in Fig 10.4. (field width 240 μm)
At all stages of interproximal reduction, the bur should be kept parallel to the long axis of the tooth to avoid the possibility of lowering the contact area. Fig 10.6 shows that even if there is some slight deviation from parallel, the effect of the ridge form (shown by the arrow Y) will prevent the bur from passing any further gingivally (providing the space between the two teeth is not great) and so keep the contact area (X) high on the tooth. This contrasts with what would otherwise occur if conventional burs were used for interproximal reduction (Fig 10.7). Here, any deviation from parallel will only cause a lowering of the contact area (shown by arrow X, Fig 10.7) because in such circumstances the bur leans against the marginal ridge area and the more occlusal enamel is preferentially removed.

For clinical use, tungsten carbide burs are best customised to three basic shapes:

(i) shoulder and short (parallel cutting surface 2.5 mm - area B Fig 10.3)

(ii) shoulder and long (parallel cutting surface 4.0 mm - area B Fig 10.3)

(iii) canine form, no shoulder - gentle curve and long (5.5 mm)
Fig 10.6. Effect on contact area of deviating from parallel using a customised tungsten carbide bur. (X - uppermost position of new contact area; Y - new marginal ridge).

Fig 10.7. Effect on contact area of deviating from parallel using a conventional dental bur. The arrow (X) indicates the direction in which the contact area is moved (gingivally relocated).
10.3. Cutting speed and efficiency of the finishing bur

Although the finishing burs are best suited for the rotational speeds of ultra-high speed air turbine handpieces, they can also be used at lower speeds. If used at lower speeds, there is some loss of efficiency and positive control, due to the higher pressure necessary to cause cutting. To some extent, the reduced efficiency can be off-set by scraping a diamond bur along the abrasive surfaces of the finishing bur to produce a very fine longitudinally scratched blade. This enhances the cutting efficiency without noticeable loss of the other characteristics (in particular, inadvertent damage to the gingival tissues).

10.4. Surface morphology following tooth reduction

The nature of the reduced tooth surface depends on the preparation techniques. Fig 10.8 shows the effects of diamond (medium); diamond (fine); custom-modified bur; and the custom-modified bur surface finished using the series of 3M XT finishing discs. Here it is seen that the diamond leaves considerable grooves on the tooth surface (Fig 10.8a), and even the super-fine diamond leaves discernible grooves (Fig 10.8b). The finished surface resulting from the customised bur (Fig 10.8c) and the
Fig 10.8. Scanning electron micrographs of altered tooth surfaces.

The enamel surface, shown on the left of each micrograph, was modified using the following burs:

(a) medium diamond
(b) fine diamond
(c) customised tungsten carbide
(d) customised tungsten carbide and finishing discs.

(field width 600 μm)
customised bur along with discing (Fig 10.8d), was considerably better than those surfaces produced by diamond burs. However, the surface left by the customised tungsten carbide bur was not as smooth (Fig. 10.8c) as a disced surface (Fig 10.8d). This is also demonstrated in Fig 10.9 (a and b) where the occlusal surface of a premolar tooth is shown, shaped using the customised bur, while the shape of a premolar tooth adjusted with both the customised bur and the finishing discs is seen in Fig 10.10 (a and b).

10.5. Clinical application

To illustrate interproximal reduction, using the customised tungsten carbide finishing burs and discs, as a satisfactory clinical procedure, the following case is documented. This patient was treated using an occlusal approach to interproximal reduction without removing the arch wires for interproximal reduction.

THE PATIENT: A 13 year old male requiring alignment and correction of a Class I malocclusion, with an estimated 6 mm deficiency of maxillary dental arch circumference.

Treatment sequence:

a) initial alignment and bite opening:
Fig 10.9. Scanning electron micrograph of a custom bur-modified premolar marginal ridge

(a) low power (field width 10 mm)
(b) higher power of section in (a).
(field width 4 mm)
Fig 10.10. Scanning electron micrograph of a custom bur-modified and disked premolar marginal ridge

(a) low power (field width 11 mm)
(b) higher power of section in (a). (field width 4.5 mm)
- to provide uprighting of all teeth
- to ensure a confluence of marginal ridges
- to ensure no rotations are present;

b) placement of separators between the teeth to displace gingival tissue;

c) interproximal reduction;

d) closing of the residual space.

Interproximal reduction was carried out using the customised tungsten carbide bur with an occlusal approach at the same visit, followed by the sequential use of the Sof-lex XT finishing discs in the series medium grit, fine grit, super-fine grit, with either the small discs or the standard diameter discs, as the clinical situation dictated. (The standard disc is suitable for occlusal and palatal surfaces; the small disc is more suitable for occlusal, palatal and occluso-buccal surfaces). The results of the maxillary interproximal reduction are shown in Fig 10.11 (a to d).
Fig 10.11. Clinical example of interproximal reduction

(a) Arch prior to treatment
(b) Teeth aligned and separators placed prior to interproximal reduction.
Fig 10.11. (cont.) Clinical example of interproximal reduction

(c) Interproximal enamel removed using the customised tungsten carbide bur.
(d) Reproximated teeth following interproximal reduction.
CHAPTER 11. DISCUSSION

"Air rotor stripping (ARS) enables the clinician to remove a precise amount of interproximal enamel to create space, primarily in the buccal quadrants for aligning or retracting teeth" (Sheridan, 1985). Sheridan states that conventional techniques, using hand-held or motor-driven abrasive strips and handpiece-mounted abrasive discs, are normally limited to the anterior teeth and can substantially reduce interproximal surfaces. However, there are problems of ensuring that an adequately controlled contour of the approximal surfaces will result. Also, such surfaces must be finished with flexible abrasive strips, and the disc placement must be exact to avoid excessive enamel loss and the creation of abnormal contacts or ledges in the enamel. The placement of these strips is generally not without discomfort and there is a risk of traumatizing gingival tissue. In order to overcome this, Sheridan has advocated a technique, using an air rotor, whereby he sequentially reduces interdental enamel in the buccal segments. The Sheridan technique (1987) proposes a sequential approach to interproximal reduction which initially concentrates on aligning the teeth. This includes reducing axial inclinations or rotations to make the contact points accessible before proceeding. The second stage is to gain an open field. He advocates that the contact area to be
reduced should be opened to provide visual access to the interproximal area. The third stage is to sequentially strip contact points from posterior to anterior, over a number of visits. He does this by using coil springs, and works from the posterior teeth to the anterior teeth, retracting and tying back after each sequential appointment. The actual technique advocated by Sheridan is to work from the side of the tooth by initially placing a 0.020 inch wire between the gingival tissue and the contact area. He then introduces a bur at right angles to the long axis of the tooth (a tapered fissure carbide) and lifts this bur up through the contact area. He then finishes the contour with a stiletto-shaped ultra-fine finishing diamond. His armamentarium consists primarily of two burs - a tapered fissure cross-cut carbide bur for gross enamel reduction; and an ultra-fine diamond for contouring and finishing the reduced enamel walls. The 0.020 inch wire placed beneath the contact, he states, serves the purpose of both tongue and cheek retraction (a crude technique).

Lyngoy (1987) also speaks of interproximal reduction, or, as he terms it, reproximation. Like Sheridan, he advocates unlocking the malocclusion conventionally before reproximation, and it may be necessary to reduce the teeth mesio-distally at monthly intervals. He suggests that this serial reduction can be an advantage
where the space gain from the mesio-distal reduction is required in order to treat anterior crowding. A reduction from the posterior to the anterior is proposed. His technique is to use diamond discs in the posterior region, and for large amounts of enamel, he suggests the use of a medium garnet or coarse Sof-lex disc. Both authors emphasise the need to provide fluoride and adequate oral hygiene instruction.

Any reduction process removes the outer enamel surface which has taken time to develop and mature, and the new, freshly exposed surface has different properties. However, Christensen and Bangerter (1987) have shown that polishing scratches on enamel did not remain permanently. This resolution has also previously been described, Saxon (1973), and Jendressen et al. (1981).

Both reports attribute resolution to covering by acquired pellicle, and show that smoothing occurs in approximately one hour. The study of Christensen and Bangerter (1987) showed the resolution took 21 to 39 days. The mechanism for scratch resolution is still unknown, however, the surfaces they studied were tooth brushing surfaces and this may have had some effect. Their study also showed that considerable care has to be taken if, after reproximating, a rubber cup is used with a polishing abrasive to finish the surface. Here, it has been shown,
considerable dentine can be removed, particularly on the root surface in the area of the cemento-enamel junction. In general, they conclude that when polishing is performed carefully (such as with a low number of revolutions per minute, a short time and decreased load with the rubber cup held at 90 degrees to the tooth surface), minimal damage occurred. The significance of the chemical and molecular structure changes brought about on this new surface is not completely understood. However, Ten Cate (1983) believes freshly-exposed enamel has an ability to mature or remineralise as a consequence of saliva being a supersaturated solution from which calcium and phosphate may precipitate onto the tooth surface.

The maximum amount of enamel which should be planned to be removed is perhaps approximately fifty per cent of the enamel surface. There are three reasons for this: a) it is clinically very difficult to ensure that you have correct angulation and some margin for error is required: if the tooth morphology is not as predicted then dentinal involvement may be inadvertently incurred; b) if the tooth is made too thin, it may be difficult to develop any interproximal gingival morphology, particularly with younger subjects; c) in some clinical situations, it can be difficult to ensure that an equal amount is being removed from each approximal surface.
The effect of notching in enamel is to create plaque retention areas. This plaque retention, according to Zachrisson (1987) can cause inflammation. In particular, this notched surface leaves an area which is not readily cleansible even through meticulous oral hygiene.

In determining the shape of the bur, a reliance was made on the shape of selected teeth obtained from the Dental Health Education and Research Foundation tooth repository at Westmead Hospital Dental Clinical School. While the sample chosen was large by the amount of material available, \( n = 10 \), it was an invasive technique of investigation, and the need to destroy a number of teeth necessitated some control over the number of teeth which were made available. As a result of this, the samples were not large enough to have significant statistics developed from them. However, what is important is that a general functional shape could be observed. This functional shape has been shown, under the scanning electron microscope, to produce a marginal ridge not unlike that which is found on teeth prior to modification. The shape of this curve (arbitrarily derived) can be given a precise equation, but once again the accuracy of this is perhaps not important, and leaves scope for further research in this field, whereby a non-invasive technique of measuring the outer surface of
the tooth could be undertaken. The teeth can be imaged, digitised and averaged for a very large number of samples to give significant results per tooth. This latter technique was not available for this research but it would have the advantage of providing a definitive shape for the particular marginal ridge shape which forms the shoulder part of the customised bur.

The advantage of the proposed technique, outlined in this thesis is that it is able to reduce, with one pass, a predetermined amount of interproximal enamel equivalent to the thickness of the parallel cutting position of the bur: in this instance, approximately 0.7 mm of tooth reduction. Should wider blanks become available from which to make the customised bur, it will be possible to have a series of blade widths from say 0.5 mm to 1.0 mm. However, it is possible to increase the width of the enamel reduction by moving the bur bucco-lingually until the desired space is obtained. This space can be determined by a feeler gauge, or by using a wire of a given thickness (1.0 mm) so that it will pass through the interproximal space. Even under such conditions, the surface produced is smooth and less likely to hold plaque than a surface produced by even the finest diamond bur. The use of the "smooth" tungstend carbide bur has the advantage of not cutting or burning the gingival tissue. If it does brush against the tissues, it does not cause
any haemorrhage, as occurs with diamond or fluted tungsten carbide burs. The speed of cutting is less than that produced by conventional tungsten carbide burs or diamond burs, but this has the advantage of better control over the amount of tooth which is reduced. The unique design of the bur has the advantage of not lowering the contact point of the tooth, but keeping it at the appropriate level. The tooth can be readily shaped and the arch wires do not have to be removed for the interproximal reduction to be carried out. This technique also has the advantage that interproximal reduction can be carried out on all teeth at once, or it can be carried out in a sequential procedure as proposed by Sheridan (1987). It is suitable for both Begg and straight-wire mechanics. The occlusal approach to interproximal reduction is similar in principle to the way crown and cavity preparation procedures are carried out in relation to the long axis of the tooth. Therefore, this technique should be much easier to orientate to than that technique proposed by Sheridan where the bur is inserted laterally and lifted towards the buccal surface. As pointed out in the Introduction, the lifting of the bur from the gingival through to the occlusal surfaces has the inherent possibility of creating ledges and notches, particularly as a tungsten carbide bur is advocated. This bur will "snatch" in and create ledges and grooves. These defects are very
difficult to detect and will result in plaque retention areas; and as such it is a technique fraught with danger for the inexperienced. It is not "user-friendly".

The custom bur can be modified easily for length, so that there is no undue gingival penetration. If the speed of cutting is slow, it can be increased by scratching the cutting surface in a vertical direction with a diamond bur so as to provide some ridges on the surface. The use of the Sof-lex XT finishing discs produces an altered surface of enamel, in most instances, as smooth as the original enamel. As the altered enamel surface has the potential to remineralise, and accept fluoride, interproximal reduction does not seem to be harmful to the surface. The effect of fluoride on the altered surface, however, depends on the frequency of its application and the concentration of the fluoride applied (Ogaard and Rolla, 1986). As such, the new proximal surface should not be any more susceptible to caries than it was prior to alteration. The surface obtained using the customised bur is also smoother than that produced by diamonds, should some surface of the tooth be left unpolished. By passing commercially available diamond burs through a contact area, even under the best conditions, it is difficult to modify the disto-occlusal or mesio-occlusal junction without lowering the contact area. This is demonstrated in Fig 10.7. More often than
not (due to lack of precise operator control) it is
lowered even further than demonstrated in the diagram and
the enamel surface which results from this cutting is
left rough. By keeping the bur parallel to the long axis
of the crown, both the marginal ridge form and parallel
surfaces are produced, and any operator error (lack of
precise vertical control) will not result in lowering of
the contact area, as the bur rests on the marginal ridge.
If necessary, the part of the tooth at "Y" (Fig 10.6) is
easily modified (as it is well exposed) by conventional
restorative procedures - such as whitestone or steel
finishing burs. The shape of the occlusal surface also
leaves it in a form which is easily modified by using
light pressure on finishing discs so that there is less
likelihood of reducing the contact area (gingivally
relocating it).

In some areas, it is not practical to reach the gingival
third of a contact area using a disc. If this should be
the situation, interproximal polishing strips of the same
grits (narrow) may be used to ensure that no small enamel
defects have been left on the interproximal surface.

There are some additional clinical considerations which
need to be appreciated for successful interproximal
reduction and reproximation. It is important to always
keep the contact point at the same gingival level pre- to
post-treatment. When trimming the maxillary teeth, trim the distal of the canines first using a contoured shoulderless bur, then follow it by trimming the mesial of the first premolar by resting the shoulder of the bur on the mesial marginal ridge, generally under direct vision. This prevents inadvertent notching on the distal of the canine surface. If the situation exists where there is high interproximal tissue, it may be best to first pass a thin customised bur with a shoulder, through between the marginal ridges of the premolars. This can then be followed by a thicker, more conventional customised bur. With any interproximal reduction, there needs to be a constant observation of the buccal surface of the crown so that the interproximal reduction bur is kept suitably aligned.

The use of a diagnostic set-up to determine the effects of interproximal stripping can be used where tooth size problems, rather than skeletal problems appear to be of consideration (Proffit and Fields, 1986, p.189). This statement is also supported by Doris et al. (1981) who say: "too often, however, the clinician will consider only those diagnostic criteria which are designed to forecast skeletal and functional changes with treatment mechanics. Our data points out that poor arch alignment is correlated with large teeth", and say conversely: "It can be stated that one of the important factors
determining whether or not a dental arch will be crowded is the absolute size of the teeth in that arch." Begg and Kesling (1977) provide an appropriate conclusion to this discussion when they say: "Perhaps proximal trimming of both anterior and posterior teeth will some day replace tooth extractions as a means of reducing mesio-distal lengths of dental arches. Naturally the fear will arise in the minds of some readers that trimming off the surface of tooth enamel proximally will cause dental caries. Experience has proved that such is not the case".
CHAPTER 12. CONCLUSIONS

An effective technique of interproximal reduction for posterior teeth has been devised and demonstrated. This involves the customising of tungsten carbide burs from commercially available burs, and using them to reduce the interproximal surface of the approximated teeth. The resultant surface of the tooth is smoother than a similar surface prepared with a finishing diamond. In addition, marginal ridge form can be developed which allows for easy finishing with the 3M polishing discs. This leaves a surface on the tooth which is far superior to any other finishing process and more approximates that of the original tooth surface for smoothness. Where any irreversible operator-technique is to be used, it must be used judiciously in well-diagnosed cases. The technique as proposed is primarily advocated for use on posterior teeth, described in this situation as being from distal of canine to mesial of first molar, although there is no reason why the distal surface of the first molar and mesial surface of the second molar could not be incorporated. The technique is perhaps most suited for adolescent or adult orthodontic patients, where gingival levels are lower, although it can be used for limited crowding cases in juvenile dentitions, as shown in the clinical example. It has been clinical experience that these burs so produced will work equally well on enamel as on finishing the surface of
dental restaurations (amalgam or composite restaurations), and will leave a surface superior to that produced by finishing diamonds.

With any tooth reduction, it is appropriate to use fluoride, and the author advocates the use of daily fluoride rinses initially. The technique is best used in conjunction with bite-wing X-rays, and it is important that all teeth be upright, aligned and de-rotated before interproximal reduction is carried out. Separators (0 modules) should be placed interproximally three to four days prior to interproximal reduction in order to remove gingival tissue close to the contact area if appropriate. In general, 0.5 mm of enamel can be removed from each approximal surface. However, it is important to be aware of the morphology of the teeth which are being altered as the reduction is not just at the contact area, but needs to carried around onto the lingual or palatal surface and to some extent onto the buccal surface of the tooth, to avoid subsequent gingival problems. If used appropriately, there is no requirement for local anaesthesia; patient acceptance of the procedure is good and the after-effects (providing there has been no dentine notching or inadvertent tissue laceration) are negligible. As with any procedure requiring alteration of tooth morphology, it is important that good oral hygiene be maintained and regular assessment of the
gingival tissues made.

In conclusion, the most clinically significant problem to be encountered when interproximally stripping teeth using the technique described, is that of loss of orientation. If orientation is inadvertently lost, more tooth on one side or the other will be removed, and the possibility of dentine exposure and a resultant mutilated dentition is increased.
REFERENCES


Ogaard, B. and Rolla, G. (1986) Retention of fluoride on


