THE PERIODONTAL STATUS OF THE ORTHODONTICALLY
TREATED PALATALLY IMPACTED CANINE TOOTH

A PILOT STUDY

JAMES SMYTH
B.D.S.(Syd) F.R.A.C.D.S.

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Department of Preventive Dentistry
Faculty of Dentistry
University of Sydney

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The University of Sydney

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This work is dedicated to my wife, Patricia, and my children who have supported me in their prayers and encouragement over the past two years and have helped me realise an ambition I have had from the beginning of my career in dentistry.
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INTRODUCTION

The problem being investigated is the peridontal status of the orthodontically treated palatally impacted canine.

The literature on the subject tends to indict our orthodontic efforts in that the final periodontal health of this tooth is not as clinically satisfactory as one would like it to be (Wisth et al., 1976, Hansson et al., 1972).

The object of this thesis is to critically review the literature on the subject and then to present the findings of clinical study carried out on finished cases.

The popular method of bonding the surgically exposed cuspid (Gensior et al., 1974, Mouser, 1980) has recently been criticised because of the necessity of a further operation in the event of bond failure before tooth eruption (Henry, 1981).

On the other hand, the technique of exposure and ligation with wire ligature has been criticised because the wire "lassoe" does not afford the control of direction of eruption. The point of application of the traction force being at the cemento-enamel junction makes the operation of ligation a difficult one and does not afford the technique of orthodontic traction any mechanical advantage over the bonding technique where the point of application of traction force is closer to the incised tip of the tooth (Mouser, 1981).

Orthodontic correction of impacted canines necessitates tooth movement in the vertical, buccal and antero-posterior directions. This is rare in orthodontic correction of sagittal malocclusions and entails surgical treatment which also may have an effect on the periodontal condition of the treated canine (Wisth et al., 1976).
Orthodontic treatment must be delayed in antero-posterior discrepancies until the palatal canine is brought into the arch. The time delay before an exposed canine has erupted sufficiently in the palate (so that a band or bonded bracket can be attached to it) can add up to 12 months to the normal treatment time (Clarke, 1971; Lappin, 1951).

The final result must then justify the efforts made by the oral surgeon and the orthodontist as well as the co-operative effort made by the patient, and, to this end, we must question the importance of the canine tooth especially where premolars may substitute for the canine (Altman et al., 1979).
1.1 THE VALUE OF THE CANINE

Lane (1962) points to the importance of the canine tooth both functionally and aesthetically - he says: "Probably the greatest tribute paid to the importance of the permanent canines is the endless number of hours that orthodontists spend, either devising a means to bring an impacted canine into occlusion or anxiously waiting to see the results of the attempt."

Dewel (1949) summarised the aesthetic and functional value of the canine tooth: "They have certain responsibilities not shared by other teeth. They assist the incisors in a cutting and shearing action and they help the posterior teeth by guiding the mandible during mastication. They contribute to facial beauty in the human by connecting anterior and posterior arch segments and by supporting the soft muscular tissues at the corner of the lips that otherwise would sink and collapse.

The special purpose of the canine is function. They have a highly developed tactile sense that helps them to protect other weaker teeth from excessive stress during mastication by taking all other teeth out of function during extreme lateral movements of the mandible. This is known as 'canine guidance' or 'cuspid protection'. By assuming the major occlusal load during mastication, the canines add materially to the longevity of the dentition."

The ideas of canine guidance put forward by Dewel (1949) have been superseded by the ideas of other workers such as Dawson (1975) who emphasise that the canine plays a supporting role in group function and that it works either with the other anterior teeth in latero trusive excursions or with the posterior teeth in the working bite to disclude the posterior teeth on the 'balancing' side.
Its role is important in that it has a longer root than the premolar or incisor teeth and it supports adjacent teeth in the manner of the 'keystone'. The occlusal function of the treated palatal canine must be respected due to the diminished bone support which this tooth often has after treatment, and it should be placed in position to work in group function with the other anterior and posterior teeth to minimise further bone loss.
1.2 PERIODONTAL PROBLEMS OF THE PALATALLY IMPACTED CANINE:

The studies done to date on this topic (Hansson et al., 1972; Wisth et al., 1976) have shown that there is an increased risk of bone loss and attachment loss and increased pocket depth around these teeth.

The reasons for these problems are clear. The palatal canine must move over long distances before being uprighted and torqued. In addition, surgery and sometimes extraction of adjacent teeth cause further bone loss as will be seen in the review of the literature later. Also, long treatment times make plaque removal all the more important, and with gingival soft tissue 'heaping' as the tooth moves labially, plaque removal becomes extremely difficult.

Recent studies show that orthodontic correction of Class II Division 1 malocclusions are accompanied by attachment loss during the treatment period, and especially so in the pressure side in closed extraction sites (Zachrisson, 1972; Zachrisson and Alnaes, 1973, 1974).

Other studies of marginal regions of orthodontically treated teeth include:


5. Gingival recession in mandibular incisors - Pearson (1968), Rose (1967).

Hansson et al. (1972) found increased pocket depth on the mesiobuccal aspect of treated canines which they attributed to insufficient cleaning during treatment, but on average, the periodontal condition was altered to only a limited extent.

Wisth et al. (1976) found that treated canine teeth showed that increased pocket depth was significantly deeper on the distal aspect and that there was more loss of periodontal support on the buccal and palatal surfaces than on the untreated teeth. However, there was more alveolar bone loss on the mesial surfaces of the corrected teeth - 2.06 mm loss compared with 1.51 mm loss on untreated teeth. Wisth et al. found that age at the start of treatment did not have any profound effect on loss of attachment, but individual variation was greater in adults.
1.3 INCIDENCE OF MAXILLARY CANINE IMPACTION

Apart from third molars, Thilander and Myberg (1973) in unselected material of Swedish schoolchildren found that of all impactions, upper canine represented 41 percent of cases. In selected material (cases referred for orthodontic treatment) the commonest anomaly after crowding was impaction - 22.4 percent of cases. Of these, 57.6 percent were upper cuspids.

Rayne (1969) reported an incidence of 1.5 percent, Bass (1967) reported an incidence of 1.7 percent of dental patients who had impacted canines. These included maxillary and mandibular canines. In the Rayne series, 6.3 percent of these were found in the mandible. In Blum's (1923) series, 9 percent of all impacted canines were in the mandible, and 51 percent of impacted teeth in the maxilla were canines.

Rayne's series (1969) had 84 percent of maxillary canines which were palatal; Bass (1967) had 91 percent palatal and Hitchin (1956) had 89 percent palatal canines. Rayne's series (1969): 25 percent were bilateral impactions; Bass (1967) and Hitchin (1956) both found 17 percent of maxillary impactions were bilateral.

It is usually stated that impacted canines are more common in the female than the male. However, this bias may be explained by the finding of Rose (1966) who stated that 60 percent of his orthodontic patients were female. This figure for sex distribution in all teenagers agrees with that of Bass (1967). Rayne (1969) reported an equal distribution in male and female adult patients, the bias toward the female occurring in the teenage groups only.
Johnston (1969) reported a 3:1 female to male bias, and he also states that he had never seen a canine impaction where serial extraction had been employed. This point is conjectural. However, it does give some credence to the theory of Dewel (1949) who believes the slow resorption of the deciduous canine root causes a deflection of the cuspid crown toward the palate.
1.4 ASSESSMENT AND DIAGNOSIS

Rayne (1969) made an extensive review of the maxillary impacted canine. The clinician should be alerted to the possibility of impaction if there is no canine bulge at the age of eight years. If by the age of ten years a displacement or impaction is suspected, radiographs should be used to provide the following information:

1. The position of the crown of the canine.
2. Pathological conditions in association with the canine.
3. The position of the apex of the canine root.
4. The obliquity of the axis of the canine.
5. The height of the crown, and of the apex of the unerupted canine relative to the occlusal plane.
6. The antero-posterior position of the apex of the canine.

Films which adequately localise the impacted maxillary canine are:

2. The Lateral Cephalometric Film.
3. The Occlusal Vertex (Seward, 1963).

The method of parallax may be applied to the periapical and occlusal films to further define the position of the tooth in the maxilla (Rayne, 1969).
To summarise, the following points are noted:

Inspection, palpation and parallax radiographs will indicate whether the canine is buccal, palatal or in line with the arch. True lateral and panoramic and occlusal radiographs will help the clinician determine the prognosis (figs. 1 and 2). The level of co-operation of the patient and the degree of severity of the impaction are taken into account.

Rayne (1969) lists a useful severity rating as follows:

**Position of root apex:**
- Grade 1: Vertically above the first premolar root.
- Grade 2: Vertically above interdental space between first and second premolars.
- Grade 3: Vertically above second premolar.
- Grade 4: Posterior to grade 3 or anterior to grade 1.

**Height of cusp of canine:**
- Grade 1: At level of necks of incisor teeth.
- Grade 2: Between grades 1 and 3.
- Grade 3: At level of apical third of incisor roots.
- Grade 4: Above incisor roots.

**Obliquity:**
- Grade 1: 60-85 degrees to occlusal plane.
- Grade 2: 45-60 degrees to occlusal plane.
- Grade 3: 30-45 degrees to occlusal plane.
- Grade 4: 0-30 degrees to occlusal plane.

**Buccal Displacement:** (See Fig. 2 (a) and (b))
- Grade 1: Related to lateral incisor.
- Grade 2: Not applicable.
FIG. 1

RAYNE'S CLASSIFICATION
ANTERO-POSTERIOR & VERTICAL DISPLACEMENTS

Key:
Number at crown tip = Grade of cusp height
Number at apex = Grade of apical position
Number at cemento-enamel junction = Obliquity

Position of Root Apex
Grade 1: Vertically above premolar
Grade 2: Vertically above interdental space between premolars
Grade 3: Vertically above second premolar
Grade 4: Posterior to Grade 3 or anterior to Grade 1.

Height of Cusp
Grade 1: At level of necks of incisors
Grade 2: Between Grade 1 & 3
Grade 3: At level of apical third of incisor roots
Grade 4: Above incisor roots.

Obliquity
Grade 1: 60°-85° to occlusal plane
Grade 2: 45°-60° to occlusal plane
Grade 3: 30°-45° to occlusal plane
Grade 4: 0°-30° to occlusal plane.
FIG. 2

RAYNE'S CLASSIFICATION
TRANSVERSE DISPLACEMENTS

(a) Buccal displacement

(b) Buccal displacement

(c) Palatal displacement
Grade 3: As grade 1, but above reflection of sulcus.
Grade 4: Cusp approaching midline.

**Palatal Displacement:** (See Fig. 2 (c))
Grade 1: Related to lateral incisor.
Grade 2: Related to central incisor.
Grade 3: As grades 1 and 2, but high in the alveolus.
Grade 4: Partial transposition.

**Treatment severity grading:**
Proposed treatment: (Rayne, 1969)
Grade 1: Exposure without traction sufficient.
Grade 2: Provision of silver cap and light traction
Grade 3: Traction with screw or wire snare.
Grade 4: Surgical removal or leave in situ.

These arbitrary grades of severity have proved useful as a rule of thumb when considering treatment. A decision is made on the basis of the most unfavourable grade which occurs for any criterion, some allowance being made for the fact that the apex tends to move during eruption of the canine, particularly when traction is exerted (Rayne, 1969).

Rayne's treatment severity grading has some application in modern orthodontics which demands that the impaction 'is' or isn't' going to be orthodontically treated. Most orthodontists would insist on some form of attachment being placed on the tooth at the time of surgery to allow good control over the movement of the tooth and to minimise the possibility of a second surgical entry, should the tooth fail to erupt. The arbitrary grades of severity are a very useful guide, however, in planning anchorage and forecasting the length of time the treatment will take.
1.5 SURGICAL EXPOSURE AND METHODS OF ATTACHMENT TO THE IMPACTED CANINE

Bishara and co-workers (1976) adequately reviewed the most commonly used surgical and attachment-traction techniques. These are summarised:

There are two methods of bringing impacted canines into the line of occlusion:

1. Surgical exposure, allowing natural eruption to occur, and orthodontic correction after eruption.

2. Surgical exposure with immediate placement of an auxiliary attachment through which orthodontic forces can be applied to move the impacted tooth to its proper position in the line of the arch.

1.5.1 SURGICAL EXPOSURE TO ALLOW NATURAL ERUPTION

This method has many advantages and is most useful when the canine has a correct axial inclination and does not need to be uprighted during its eruption. The progress of canine eruption should be monitored with frequent roentgenograms.

Clarke (1971) treated 2,000 cases successfully by the above method, but he used polycarbonate crowns placed over the impacted tooth. His technique can be summarised as follows:

1. A palatal flap is laid back and overlying bone is removed to expose the crown. It is essential that all bone and soft tissue is removed to expose the crown.
2. The impacted canine is luxated gently.

3. A polycarbonate crown is fitted to cover the entire crown of the canine and should be made long enough to extend through the window cut in the palatal tissue. The crown is then cemented with surgical paste or regular cement.

4. Prior to suturing the palatal tissue, a trough is cut through the cortical plate from the impacted canine to the alveolar ridge to facilitate tooth movement toward the arch. Upon eruption, the crown is removed and a bond or bonded bracket is placed for final tooth movement. If the tooth fails to erupt, it is necessary to remove any cicatricial tissue surrounding its crown. Clarke indicated that, after a palatally impacted canine has been brought into the arch, lingual drift can be prevented by removing a halfmoon shaped wedge of tissue from the lingual aspect of the canine down to the bone.

Von der Heydt (1975) favours the technique of packing around the crown of the tooth with softened baseplate gutta-percha. A second pack of surgical cement prevents healing of the mucosal opening. The gutta-percha is used to stimulate movement of the crown of the tooth toward the oval cavity away from the roots of the adjacent teeth. Frequent changes of dressings are required.

Helmore (1967) also advocated stimulation of the impacted tooth and he claims that once the physical barrier is removed, the eruption urge of the tooth, which is strongest around the time normal eruption is expected, will cause the teeth to erupt. Helmore claims a 90 percent success rate with this technique.
Masson (1981) disapproves of stimulation due to the possibility of the tooth becoming ankylosed, and favours surgical exposure only, to allow natural eruption.

Thilander et al. (1973) in a study of surgical exposure on unerupted teeth of which 51.3 percent were maxillary cuspids, found that 68.3 percent of the unerupted teeth erupted either partly or completely with surgical exposure alone, regardless of the age of the patient.

Johnson (1964) favours surgical exposure and removal of follicle and bony covering, followed by creation of a trough to the alveolar ridge. Wound closure is completed by replacing the flap and covering with Orahesive bandage. After eruption he places a cast cap for traction which is commenced an average 4-6 months after surgical exposure.

1.5.2 SURGICAL EXPOSURE WITH PLACEMENT OF AN AUXILIARY

After surgical exposure of the impacted tooth, an auxiliary is attached to its crown, either directly to the enamel or indirectly to a band or crown. Orthodontic forces can be transmitted to this attachment for the purpose of moving the tooth into the line of the arch. Two methods are generally accepted:

1. Lewis (1971) preferred a two-step approach. First the canine is surgically uncovered and the area packed with surgical dressing to avoid filling in of tissues around the tooth. When, after three to eight weeks the wound has healed, the pack is removed and a band or other attachment is placed on the impacted tooth.
2. The second method is a one-step approach. The attachment is placed onto the tooth at the time of surgical uncovering.

1.5.3 METHODS OF ATTACHMENT

(a) Wire: A dead soft 0.020 inch brass or stainless steel round wire is passed below the cingulum of the impacted canine with the ends of the wire twisted in pigtail form and allowed to extend through the palatal tissue. This method sometimes demands considerable surgical skill and is at times impossible because the impacted tooth is too close to adjacent teeth.

Zeigler (1977) favours this technique and has developed a "modified technique" for ligating canines (see fig. 3). He claims the wire is very small and kind to the tissues - a point well worth noting if we are to preserve the periodontal health of the tooth.

(b) A variation of the above method is to attach a gold chain to the wire wrapped around the tooth. A light round wire (0.014 inch) is then soldered to the main arch wire in a fully banded case. The end of the auxiliary wire is bent in the form of a hook. To activate the system the hook at the end of the auxiliary wire is attached to one of the links of the chain, thus applying tension on the tooth. Another use of the chain is to monitor the movement of the impacted tooth by counting the number of links coming out of the tissue in consecutive visits.

(c) Band: A band can be fitted and cemented at the time of surgery (with a bracket, cleat or button welded to it) if all the surfaces of the crown of the impacted canine are uncovered. The corresponding tooth in the same arch can be used as a guide in choosing a suitable band for the unerupted tooth.
FIG. 3

Ziegler's modified ligation chain, consists of 15 cms of 0.305 cm round stainless steel wire looped around an 8 mm dowel at its midpoint. The wire is twisted and then looped around a 2 mm dowel so that a series of 2 mm eyelets are made. These eyelets facilitate threading of elastic ligature and as each eyelet passes through the tissue, it is threaded with elastic ligature to maintain continuous tension on the erupting tooth.

FIG. 4

Gold chain welded to stainless steel band material which is welded to 60 gauge stainless steel mesh. Scalp vein tubing provides temporary handle whilst bonding takes place. Tubing is removed then chain is ligated to adjacent tooth or arch wire for activation.
(d) Cast gold crown or only: After the canine has been uncovered and packed and the tissues have been allowed to heal, an impression is made of the exposed position of the canine and a gold onlay with a hook or eyelet is constructed and cemented to it. The impression for the crown could also be taken on the opposite tooth in the same arch if the crown is to be fabricated before surgically exposing the impaction. Johnson (1979) and Lewis (1971) favoured this method.

(e) Threaded pin: A hole of appropriate size is drilled in the tooth and a pin is threaded or cemented into it. To avoid pulpal exposure the pin is placed in the disto-lingual aspect of the canine if this is visible upon exposure. When the tooth has erupted, the pin is cut off and burnished to the enamel surface. A band or bonded bracket is then placed for final tooth alignment. There is a danger of exposing the pulp, or, if the pin is dislodged, caries may begin, or there is the possibility of enamel fracture if the pin is not placed strategically. Dewel (1949) cautioned against any permanent destruction of tooth structure. The advent of bonded attachments has largely superseded the technique of pinning.

(f) Direct bonded attachment: Adhesives can be used to bond an attachment directly to the tooth at the time of surgery or after its partial eruption. One problem with this method is the difficulty in obtaining a dry field which is necessary for bonding. Mouser (1980) suggests that the application of the phosphoric acid etching solution to the surrounding tissues provides adequate haemostasis and his technique of using a piece of scalp vein polythene protecting sleeve over the chain to provide a semi-rigid handle to aid in positioning the mesh pad (with gold chain attached) on the exposed cuspid, has met with great success. (See fig. 4 )
When the canine has erupted and has moved quite near to the line of occlusion, the mesh pad with chain is removed and replaced with a conventional bonded bracket for final alignment of the tooth.
1.6 ORTHODONTIC MANAGEMENT OF THE PALATALLY IMPACTED CANINE

The principles of orthodontic management have been adequately reviewed by Bishara et al. (1976):

1.6.1 ONE-ARCH Vs TWO-ARCH TREATMENT

Most orthodontic cases do require banding of both maxillary and mandibular arches in order to achieve the desired biomechanical control necessary for optimal results.

The lower arch can be used to great advantage in helping to position the impacted canine in proper occlusion. This is especially true in horizontal impaction. A heavy archwire 0.022" round or 0.018" x 0.025" rectangular wire is used in the lower arch which distributes the reactive force over the whole lower arch thereby minimising adverse tooth movement. A cross elastic from a hook or cleat attached to the palatal canine is attached to the lower bicuspid area. (See Fig. 5)

If one arch is used, undesirable tooth movements may occur and difficulties arise in co-ordinating the upper and lower arches. To prevent some of the undesirable sequelae of one arch treatment, four considerations should be kept in mind.

1. Light forces should be used for canine extrusion.
2. A continuous tie or stop of the teeth mesial and distal to the canine area may be indicated after space for the canine has been treated.
3. A heavy one arch should be present to resist the deformation caused by the extruding force.
4. The lower arch should be reasonably well aligned and levelled.
1.6.2 CUSPID Vs PREMOLAR EXTRACTION

The prognosis of successfully exposing and guiding the canine to its proper position is often guarded (Bishara, 1976). In those cases requiring extraction of the upper premolar, it is worthwhile to consider extraction of the impacted canine instead, in view of the difficulties involved in the successful treatment of the difficult impacted canine (Altman, 1979).

Where there is a choice of treatment alternatives, the premolars are not extracted until the prognosis of the impacted canine(s) is determined.
1.7 **ORTHODONTIC APPLIANCES**

Several configurations are illustrated to show extrusion mechanics after surgical exposure of the tooth in the palate. The most popular methods are listed:

1. Elastic tie to vestibular arch wire. (Fig. 6(a))
2. Buccal whip extension from the distal end of the arch wire. (Begg, 1965). (Fig. 6(b))
3. Auxiliary spur soldered to main arch wire. (Fig. 6(c))
4. "Safety Pin" auxiliary. (Fig. 7)
5. Palatal whip spring.

For extrusion of the canine from its bony crypt, the author favours the Ballista spring system designed by Jacoby (1979). It has several advantages over other systems:

1. It creates a vertical traction toward the middle of the palate away from the roots of adjacent teeth. By modifying the vertical part of the spring, one can control the direction of eruption. If the spring is inclined forward or backward it adds these components to the vertical traction. By lengthening the vertical part of the spring, it adds a force towards the midline of the palate, and by shortening, it adds a force toward the dental arch. Once the Ballista spring is attached to the hook, it becomes tangent to the oral mucosa and does not disturb the patient.

2. The Ballista spring is easily inserted and ligated. It provides a continuous force that is well controlled and easily modified. Usually, by changing two or three springs one can obtain the complete marsupialisation of the canine's crown in the oral cavity.
Cross-elastics

(a) Elastic tie  (b) Buccal whip extension  (c) Soldered spur

FIG. 8

PALATAL WHIP SPRING

(a) Occlusal view

(b) Lingual view

(i) Spring inserted passively and ligated to premolar bracket, palatal anchorage is .045" wire soldered to first molar and first premolar bands. Helix ligated to molar tube.

(ii) Spring is either .016" wire (delivers 60-100 gms of force) or .018" wire (delivers up to 150 gms of force).

(iii) When spring inclined forward (A) or backward (B), it adds a forward or backward traction to the vertical component.

(iv) When it is lengthened (C) or shortened (D) it adds a median or lateral traction.
3. The system does not require any banding of anterior teeth during marsupialisation. At a later stage, when the crown erupts completely, the anterior teeth and canines are bonded or banded. The second stage involves the normal placement of the canine in the dental arch with proper torque.

4. A conservative surgical exposure is required, sufficient exposure being necessary to bond an attachment to the crown of the tooth.

5. The spring may be modified to retract impacted upper incisors, impacted premolars and molars. Only the degree of imagination of the practitioner is a limit to the system.

    Most impacted teeth are in close proximity to the roots of the adjacent teeth. A simple straight traction between the impacted tooth and the vestibular arch wire means the compression of the impacted tooth against the roots of the adjacent teeth with failure in the treatment.

    Movement of the crown of the impacted tooth away from the roots of adjacent teeth is necessary to preserve crestal bone. Sheared crests of interproximal bone may result in the "direct pull" technique where the crown moves bucco-lingually to the lateral incisor.
FIG. 10 BALLISTA SPRING

Showing spring on right activated.

FIG. 11 PALATAL WHIP SPRING
PART 2

LITERATURE REVIEW
2. LITERATURE REVIEW

INTRODUCTION

The literature review will deal briefly with the effects of tooth movement, iatrogenic damage by appliances, and finally, with the effects of surgery and extraction on the periodontum of the maxillary impacted canine.

Each of these factors may influence the periodontal status of this tooth and by taking each factor into consideration, we may then recommend ways and means of minimising any adverse effects from these various treatment entities.

2.1 EFFECTS OF ORTHODONTIC TOOTH MOVEMENT ON THE PERIODONTIUM

2.1.1 GINGIVAL EFFECTS

Atherton and Kerr (1968) describe the appearance of the gingiva when a tooth has been moved distally through alveolar bone (canine or premolar retraction) adjacent to the "side of tension". There is a triangular red patch and the mesial surface of the tooth exposed in the mouth is increased in size by the amount which corresponds to this red area of epithelium.

They infer that this red patch is formed by the peeling off of the enamel epithelium in the "wake" of the tooth. On the "pressure side" when the tooth is moving into the space created by the extraction of the tooth distal to it, the papilla distal to the tooth appears to be displaced by the movement, and creasing occurs in the epithelium over the socket. A follow-up of thirty patients up to two years after tooth movement showed that the changes were not permanent.
The gingival changes reported here are not backed up by pocket depth or attachment loss recordings. Therefore, this study is not entirely meaningful.

Pearson (1968) studied gingival recession in orthodontic patients. He compared the clinical crown heights of lower central incisors in subjects who had had orthodontic treatment, with the clinical crown heights of non-treated individuals. The control group showed little change over the two year period of the study and the experimental group resembled the control group in that no significant correlations appeared when comparing the different types of incisal movement with the amount of gingival recession.

Gingival recession in this age group is a natural consequence (Baer and Coccaro, 1964) and also the lower incisor is possibly the least moved tooth in a fully banded treatment program. Any effects seen here may be entirely due to the effect of the appliance rather than tooth movement.

Kloehn and Pfeifer (1974) studied clinical crown height before and after orthodontic treatment. They found a negligible increase in clinical crown height. They concluded that the small changes that did occur could be the result of:

1. Passive eruption.
2. Elongation of teeth during treatment.
4. Changes in the amount of gingival inflammation.

Their clinical study was done four months after band removal. This is only a short term study - periodontal defects may take some years to develop after their initiation.
Zachrisson (1972) studied the gingival effects of orthodontic treatment by taking biopsies of gingiva from teeth undergoing orthodontic treatment. He concluded that the gingival changes seen during treatment represent a reaction to the bacterial plaque products rather than to orthodontic forces. After band removal the tissue gradually returned to its normal histologic appearance within a short time. The biopsies in this study were taken from the buccal aspects of first molars which moved little, if at all during treatment. Therefore, the material was hardly suited for supplementation of earlier studies on gingival reactions to tooth movements like rotation (Reitan, 1959, 1967) and retraction (Atherton, 1970; Atherton and Kerr, 1968).

The histological observations in this study generally confirmed the clinical demonstration of gingivitis. However, in agreement with earlier findings in orthodontic (Spence, 1955) and non-orthodontic patients (Zachrisson and Shultz-Haudt, 1968), the degree of correlation between histological observation and clinical assessment on individual specimens was moderate.

Zachrisson and Alnaes in a later (1973) study on fifty-one individuals representing Class II, division 1 four first premolar extraction cases subjected to full orthodontic treatment by a light wire edgewise technique, found that crown height was virtually the same when compared with a matching non-orthodontic group.

This agrees with the findings of Pearson (1968) who found that severe gingival recession buccally on lower central incisors occurred in only a small percentage of cases.

In an experiment on beagle dogs, Ericsson et al. (1978) showed that, in the absence of plaque, orthodontic forces moving individual teeth bodily in these dogs did not induce gingivitis.
The results are different from Zachrisson's 1972 study, because appliance design was different.

In the Ericsson et al. study the orthodontic bands were applied on the teeth in such a way that the marginal border of the appliance was always located several millimetres above the gingival margin. Also in this study, presence or absence of gingival inflammation and loss of connective tissue attachment was always assessed in histological sections whereas Zachrisson was able to use biopsy material only, because of the limitations imposed on his use of human subjects in his experiments. The biopsy was a small piece of gingiva, 2 mm square, taken from the buccal gingival margin of the lower first molar tooth.

Alstad and Zachrisson (1979) did a longitudinal study of the periodontal condition associated with orthodontic treatment in adolescents.

They studied the following details before, during and after fixed band edgewise treatment:

1. Plaque situation by means of the plaque index system (Löe, 1967).

An intensive preventive program was carried out for all patients in the study and the results reflected the virtue of such a program because the oral hygiene and gingival condition was good or excellent throughout the treatment in the treated subjects.
A significant finding in the study was that after treatment, the state of hygiene was better at the same age in the treated than in the untreated persons.

They also noted that no differences were registered during active therapy and after the removal of the fixed appliances, the orthodontic patients had significantly lower plaque scores and less gingivitis than the untreated persons.

The results here demonstrate the irrefutable fact that the appliances cause plaque retention and a strong preventive program minimises the deleterious effect of plaque retention and has the added future benefit for the patient in that he will be better motivated in oral hygiene procedures after orthodontic treatment has finished.

Conclusion

It appears from these studies that orthodontic tooth movement has little effect on the long term health of the gingiva.

The effects on the gingiva are more likely to be caused by the plaque-retaining capacity of the appliances and the patients' inability to remove the destructive plaque.
2.1.2 EFFECTS OF TOOTH MOVEMENT ON POCKET DEPTH AND ATTACHMENT LOSS

Brown (1973) reported on the uprighting of molars in the periodontally compromised dentition as evidence that orthodontic procedures consistently produced teeth with favourable axial inclination, and contributed to the restoration of a normal occlusal plane and landmark relationships. This therapy produced significant reduction in the depth of periodontal defects and highly desirable changes in the gingival architecture to the extent that lesions would (if surgical intervention was indicated) be more amenable to conventional periodontal techniques, and, that after achieving complete pocket elimination, restorations exhibiting normal form and function would be assured.

In Brown's study, periodontal treatment, that is, scaling and root planning was carried out after commencement of orthodontic uprighting. There was no control group where periodontal therapy only was carried out, thereby taking away the value of this study.

Further to Brown's work, Ingber (1974) has moved teeth into infra-bony defects of the two and three walled types and have noted the healing and regeneration of bone in these situations.

Zachrisson and Alnaes (1973) evaluated loss of attachment, gingival pocket depth and clinical crown height in a group of 51 young orthodontic patients. They received no special attention with respect to oral hygiene care following active retention. They were examined two years after fixed appliances had been removed. Fifty-four matching young adults who had not had any orthodontic treatment served as a reference group. The results showed that slight damage had occurred consistently with the orthodontic intervention in some of the individuals.
Mean loss of attachment was 0.41 mm in the orthodontic group and 0.11 mm in the reference group. The individual variation was large.

In a later similar study Alstad and Zachrisson (1979) found that there was no marked periodontitis in any patient following band removal after a full period of orthodontic treatment. Generally, the degree of breakdown among all test persons was negligible with mean figures of less than 0.1 mm loss of attachment per person.

These results are at variance with the clinical findings of the earlier cross-sectioned study by Zachrisson and Alnaes (1973) in which slight but statistically significant differences in mean loss of attachment were found between post orthodontic and untreated adolescents.

Possible explanations for the discrepancies are:

1. Differences in method.
   The measurements in the earlier (1973) study were restricted to four facial surfaces.

2. The registration method used a steel strip technique which allowed measurements to the nearest 0.5 mm. In the later (1979) study, thirty-six surfaces were registered on five different occasions for each person and probe measurements to the nearest 1 mm were made. Zachrisson agrees that probe measurements are subject to several problems such as -
   a) Inability to standardise insertion forces.
   b) Inability to read the graduation accurately.
   c) Inability to predict the extent of penetration in healthy and inflamed tissues. (Armitage et al., 1977; Robinson and Vitek, 1980).
3. Tooth brushing habits.
Zachrisson states that part of the breakdown on facial surfaces registered in the 1973 study was due to overzealous brushing. The patients in the 1979 study had oral hygiene instruction at every visit and the instructions were carefully followed by every patient. This resulted in treated patients having a significantly lower plaque score and less gingivitis than the untreated control group.

In the Kloehn and Pfeifer study in 1974, sulcus depth was measured before, during and after orthodontic treatment of fifty-one subjects. They found no appreciable increase in sulcular depth after orthodontic treatment. They were fairly generous in their estimates of gingival hyperplasia because the measurement of 4 mm was chosen as the depth beyond which a recording was made on the periodontal chart.

Before orthodontic treatment in this group, there was a total of 176 areas where tissue hyperplasia resulted in a sulcus depth of 4 mm or greater. Following orthodontic treatment the number of hyperplastic areas resulting in a deepened sulcus was reduced to twenty-eight with none in the anterior area.

Four millimetres was selected because, at this depth, inflammatory changes are usually noted at the bottom of the sulcus when studied histologically.

The high prevalence of gingivitis prior to orthodontic treatment as indicated by Russell's periodontal index concurs with the findings of Jamison (1963), Parfitt (1957), Ramfjord (1961) and Sheiham (1969).
Erickson et al., in their dog experiments in 1978, clearly demonstrated that in the absence of plaque, bodily movement of teeth did not cause any appreciable attachment loss, but tipping forces where plaque was present did cause additional loss of periodontal tissue support.

This study is not entirely reasonable in that it is comparing different types of tooth movement with different degrees of plaque control. The experiment was designed to show the effect of plaque when carried below the marginal gingiva in a tipping movement and the bone loss was no different from orthodox bodily movement under ideal conditions, that is, where there was no plaque.

Conclusion

Loss of attachment and increased pocket depth is minimal if a strict preventive program is followed by orthodontic patients. There is an occasional exaggerated response in the individual which may be due to the increased tendency to gingivitis in this age group.

Generally speaking, orthodontic therapy does not alter or appreciably affect the gingival status or pocket depth or attachment loss in the absence of plaque. This fact must be weighed against the evidence shown by Lennon and Davies (1974) who demonstrated that in 46 percent of a group of 15 year old school children attachment loss of greater than 1 mm occurred and of these, 11 percent had attachment loss of greater than 2 mm on at least one tooth. It would therefore be presumed that the orthodontically treated palatally impacted canine would have at least this degree (greater than 2 mm) of attachment loss considering the surgical, orthodontic and increased plaque retention influences on this tooth.
2.1.3 EFFECTS OF ORTHODONTIC TOOTH MOVEMENT ON CRESTAL BONE HEIGHT

Correcting the impacted maxillary canine after surgical exposure entails both vertical, transverse or tipping and sometimes rotational and torquing movements (Clarke, 1971; Helmore, 1967; Lewis, 1971).

The transverse movement will result in the labial plate of bone being the side of pressure. This will be a site of potential periodontal destruction (Sleichter, 1971; Zachrisson and Alnaes, 1974).

The labial root uprighting of the canine will result in a pressure zone being created at the palatal alveolar crest with a consequent loss of bone height palatally (Wisth et al., 1976).

Reitan (1972) warns of the possibility of bone destruction from tipping teeth in a labial direction. This occurs quite often in adult teeth and sometimes in young patients. However, in most young patients, compensatory bone deposition follows the resorption from moderate tipping in a mesio-distal direction (Reitan, 1975).

Teeth having adequate attached gingiva occasionally develop localised recession during orthodontic treatment. It has generally been assumed that such destruction has been associated with excessive forces that have not permitted the repair and remodelling of the alveolar bone.

It is more likely that the direction and extent of the movement have forced the tooth through the cortical plate producing a dehiscence. This concept is supported in cases of severe gingival recession consequent to tooth movement, in which the remaining gingival attachment appears relatively free of inflammation (Geiger, 1980).
Very few studies have been carried out in crestal bone destruction as a consequence of orthodontic tooth movement. The Panoramic x-ray technique was used by Tirk et al. in 1967 to study periodontal tissue response in orthodontically treated subjects. However, their findings were inconclusive.

Baxter (1967) in an intra-oral serial study, measured alveolar crest heights in extraction cases in the area of extractions, but he found no significant loss of crest height during space closure and orthodontic treatment.

Weber (1971) reported on a series of investigations related to the use of the Begg technique at the University of Tennessee. One graduate student (Libby) in this series measured the heights of the crests of the interproximal alveolar bone at the mesial and distal aspects of each maxillary and mandibular second premolar using a standardised radiographic technique. He found no significant bone loss on the extraction side and the non-extraction side of twenty-five treated cases out of retention. Weber's paper was a summary of work done by graduate students. He did not enlarge on the technical details of methods of measurement.

Sjolien and Zachrisson (1973) compared bone support and tooth length in a series of orthodontically treated patients with the data from a matching group of untreated persons. All were Class II division 1 first premolar extraction cases treated by the edgewise technique. They were examined two years after treatment was completed. The results demonstrated that persons who had received orthodontic treatment had significantly shorter teeth with less periodontal support than had the control subjects. This study showed that bone loss was most marked on the mesial and distal surfaces of the maxillary and mandibular canines.
The most marked difference between the two groups of patients, therefore, were observed in the closed extraction spaces and in the maxillary anterior region. The findings that the reduction in bone support was more marked on the pressure sides than on the tension sides following closure of extraction spaces, also corroborate the findings of Zachrisson and Alnaes (1974).

This later study attempted to use strictly standardised material and technical procedures to estimate the interdental alveolar crest heights in the two groups of patients (one group treated and one group untreated). The distance between the cemento-enamel junction and alveolar crest on average was 1.11 mm in the treated group and 0.88 mm in the untreated group. They also noted that the distribution pattern demonstrated considerable individual variation, some 10 percent of patients showing a predisposition to more definite alveolar bone loss than other patients.

2.1.4 CONCLUSIONS

On the basis of histological observations, Schei and co-workers (1959) considered bone loss to have taken place when the alveolar crest was found to be more than 1 mm from the cemento-enamel junction. This point will be discussed in section 3 of the thesis.

The Sjolien and Zachrisson (1973) study showed definite bone loss in treated cases which was considered to be within an acceptable range to be compensated for by the achievement of good treatment results.

Zachrisson and Alnaes 1974 study concluded that there was significantly more bone loss in the treated group.
Both studies were on patients who had extractions and who had Class II Division I malocclusions treated. These cases require closure of extraction spaces and usually require quite a lot of distal movement of upper incisors. The extent of bone loss depends on how much movement is carried out and the type of force used, degree of tipping and uprighting, and also the individual predisposition to bone loss.

Perhaps a study using a bigger cross-section of patients would reveal more truly the extent of bone loss and whether this bone loss is related to the extent of tooth movement carried out, or is due simply to individual predisposition.
2.2 IATROGENIC DAMAGE BY APPLIANCES

The impacted maxillary canine presents many problems as far as appliance irritation is concerned. The attachments are often placed before the tooth has erupted. The appliance is therefore acting as an irritant to the palatal mucosa until the tooth has erupted.

Once erupted, the lingual position of the cuspids together with the presence of traction mechanics, results in an increase in the number of retention areas causing an accumulation of bacterial plaque along the free gingival margin (Brandtzaeg, 1966). Also, the reaction to the metal bracket or band and extruded cement in the gingival pocket poses an aggravating effect on the tissues, not so much from the presence of the irritant, but from the retention of plaque on the band, bracket or cement (Waerhaug, 1957; Zachrisson, 1972).

Baer and Coccaro (1964) reported on three cases of gingival hyperplasia during orthodontic treatment. They suggested that the bands encroached on the gingival papilla acting as an irritant. They believed that good oral hygiene is enough to counter the irritating effect of appliances. They also drew attention to the fact that the age group which is receiving orthodontic treatment shows an increased tendency to gingivitis.

Parfitt (1957) reported a prevalence of 90 percent gingivitis in children over the age of 11 years. Cohen (1955) believes that some gingival enlargement in the anterior segment of the mouth is so common in the prepubertal and premenarchial period that it has been called an additional sign of beginning of pubescence.
Levine (1970) also refers to the pubescent changes which cause an exaggerated response to a minor irritation. He claims that bands placed deeply in the gingival crevice can severely damage the epithelial attachment. He refers to the case of periodontal abscess as a result of deep band placement.

Judge (1974) wrote that bands placed subgingivally caused moderate inflammation and increased pocket depths, even after a suitable healing period. They caused in some cases root surface damage and apical proliferation of the epithelial attachment. He claims that bands which penetrate the epithelial attachment would appear to cause permanent increases in pocket depth.

Waerhaug (1957) demonstrated that stainless steel ligatures could be inserted in healthy gingival pockets without causing any long term inflammatory changes, provided that bacterial plaque did not adhere to the wire.

Rovin et al. (1966) further substantiated the effect of plaque on the gingiva in his experiment on gnotobiotic animals when he demonstrated the lack of response to silk ligatures around the necks of the teeth in these animals.

These experiments showed the effect that mechanical plaque retention around the teeth caused a rapid worsening of the inflammatory lesion with increased plaque accumulation. (Rovin et al., 1966; Kennedy and Polson, 1973).

Kloehn and Pfeifer (1974) studied the relationship between orthodontic treatment and periodontal disease. They found that the incidence of hyperplasia was greater in posterior areas of the mouth than in the anterior areas, and was greater interproximally than at the centre of the crown.
They claim that the reasons for the variation are that:

1. Mechanical irritation by the bands which are more likely to come into contact with the gingiva around the posterior teeth rather than the anterior teeth.

2. Chemical irritation by the cement margin at the gingival margin of the band.

3. Greater likelihood of food impaction in the posterior areas of the mouth due to the proximity of the arch wire to the soft tissues.

4. The tendency for more effective and through brushing of the anterior than the posterior teeth.

They found that hyperplasia diminished dramatically within 48 hours of appliance removal and continued to decrease during the first four months of retention.

The patients in this study had oral hygiene instruction at each orthodontic visit, and it was noted that the percentage of patients who were able to maintain an "0" periodontal index (Russell, 1956) whilst orthodontic appliances were in place dropped from 20 percent to 6.5 percent of patients. It is deduced, therefore, that some patients simply cannot escape the irritation caused by the appliances themselves.

Zachrisson (1978) stated that gingiva of bonded patients can be kept in an almost normal condition which is seldom seen in banded patients - the banded patient has more irritation in the proximal col due to the presence of excess cement and poorly fitting bands.
Alstad and Zachrisson (1979) claim that there were no statistically significant differences in the loss of attachment between banded and bonded subjects. In this study, the patients underwent an intensive preventive program which may explain their excellent periodontal health after orthodontic treatment.

Appliances include the bonded bracket: The modern method of retrieving the palatally impacted maxillary canine is to surgically expose and bond an attachment to the tooth to which the traction force is applied. (Mouser, 1980). The bonded bracket, therefore, becomes a subgingival irritant until the tooth has erupted. There is ample evidence of the irritant effect of excess bond flash on the gingiva (Zachrisson, 1978), although it is apparent from several studies that the irritant effect is more from the plaque retained on the rough surface of the bond flash, rather than from the flash itself (Kloehn and Pfeifer, 1974; Kessler, 1976).

Waerhaug (1975) and Silness (1970), agree that subgingival restorations complicate plaque removal and thus favour the development and maintenance of gingivitis and periodontitis.

Steel ligature wire appears to be the least irritating when it comes to plaque retention. However, the disadvantage of greater bone removal in achieving successful ligation with a steel ligature lasso outweighs the likelihood of some irritation and consequent bone loss by plaque adhering to the bonded retainer and gold chain attachment. If the surgeon attempts to tighten this lasso by twisting the wire ends, the effect could be to force the lasso in the apical direction due to conical root shape, thereby increasing the stripping of attachment below the cingulum (cemento-enamel junction) and not forgetting the possible risk of causing eruption of the apex rather than the crown of the tooth.
CONCLUSION

It is apparent that with the palatally impacted canine tooth, irritation by retained plaque is more damaging than the irritant effects of the appliance, be it a bonded bracket or cemented crown or band, or steel wire lasso.

In the studies done to date on plaque and gingival scores related to the palatally impacted maxillary canine, the scores have been carried out after the orthodontic correction had taken place. It is during treatment that damage to the periodontium from plaque is a factor in the final outcome of the periodontal status of the canine tooth.
2.3 EFFECTS OF SURGERY AND EXTRACTION ON THE PERIODONTIUM

Histological evidence from animal experiments has shown that the alveolar crest will not return to its former height adjacent to extraction sites (Zachrisson, 1978; Furltman, 1972; Silness et al., 1973; Ash et al., 1962).

Periodontal changes have been ascribed to the excessive surgical removal of labial alveolar bone (Broadway and Gould, 1960).

Nyman et al. (1979) studied the effects of surgically removing buccal alveolar bone from the roots of premolars in dogs. They found that new cementum formation and fibrous re-attachment occurred in the supra-alveolar area between the marginal bone crest and the junctional epithelium. In two out of the eight test areas studied did the alveolar bone regenerate to or close to the normal distance from the apical portion of the junctional epithelium, whereas in the remaining six areas, a long supracrestal connective tissue attachment was present.

Altman et al. (1979) drew attention to those cases where extraction of dental units is required in orthodontic treatment. Where there is impaction of the maxillary canine, thought should be given to extraction of the canine, thereby circumventing the problems which may beset the treated canine.

Cohen (1962) demonstrated that removal of follicle from unerupted teeth seemed to provide an attachment which maintained the initial gingival contour at a high coronal level. As oral epithelium gradually replaced enamel epithelium, however, progressive gingival recession would occur until the final adult clinical crown length was achieved.
This proposed maturation process is hastened by surgical removal of the epithelium since the means of maintaining a high gingival level had been lost, and rapid gingival recession would occur. If gingival recession is the result of excessive bone removal, it would be reasonable to expect a rough correlation between the amount of labial plate removed and the degree of gingival recession which finally occurs. In practice, such a correlation is very difficult to demonstrate. Indeed, recession occurs where no bone has been removed at all. Moreover, even assuming that surgical bone loss was the prime cause of soft tissue recession, this would still not account for the absence of gingival tissue as distinct from alveolar mucosa which is a prominent feature of the problem - especially with treated labial impactions. Cohen, therefore, concludes that bone removal is not the major aetiological factor in gingival recession.

Furstman and Bernick (1972) in animal studies found that there was a marked loss of bone following extractions. Alveolar bone is almost completely lost to the level of the apical region on the teeth adjacent to the extraction site within a period of fourteen days after the extractions. Subsequent repair reveals that the interproximal bone never restores itself to its former height. A dense pad of connective tissue in the extraction area seems to prevent the restoration of bone. Furstman and Bernick remind us that the alveolar bone is developed in response to the eruption of the tooth and the growth of the periodontal ligament. They do not recommend enucleation or early removal of teeth prior to orthodontic treatment, but state that rapid space closure shortly after extractions minimises the formation of the dense pad of connective tissue and permits the alveolar bone to regrow to a more normal level.
Silness, Hunsbeth and Figenshau (1973) studied the effects of tooth loss on the periodontal condition of neighbouring teeth. They found that although there was reduced pocket depth, there was loss of bone height on the distal surface of the neighbouring tooth.

Ash et al. (1962) found a similar occurrence on the distal surface of second molars after extraction or surgical removal of the neighbouring third molar.

Heaney and Atherton (1976) advocate the avoidance of surgical exposure whenever possible. Exposure of a buccally placed unerupted tooth with subsequent eruption into unkeratinised alveolar mucosa results in periodontal pathology characterised by absence of a functional zone of attached gingiva and increased clinical crown length. These changes in turn result in an increase in the severity of periodontal inflammation.

If the tooth is palatally placed, it is unlikely that all the future attached gingiva will be lost even when considerable quantities of mucous membrane are removed. Functional gingival zone will always be present, although some degree of recession may still occur.

Wisth (1975) assessed gingival health, pocket depth and loss of fibre attachment of mandibular first molars and first premolars after the embedded second premolar had been surgically removed on one side and extracted on the other side and spaces closed orthodontically. He found that there was a greater risk of attachment loss on the buccal of the first molar tooth after surgical removal and also there was greater constriction of the alveolar process after surgical removal than after extraction. Yet he observed that there was radiographically more bone loss interproximally on the extraction side.
This he attributed to the fact that, on surgical removal of the impacted tooth, some interproximal bone is left buccally or lingually which is then superimposed on the radiograph. The conclusion of this study was that the surgical treatment did not affect the morphology of the alveolar process adjacent to the teeth in a way that plaque retention was increased, and that the depth of gingival pockets was similar in both groups.

Whilst this study bears important and relevant information with regard to the study at hand, it should be remembered that there is an important difference between the maxillary and mandibular alveolar bone. The cortical plate of bone is much thicker in the posterior areas of the mandible than in the anterior areas of the maxilla. Therefore, surgical removal of bone in these respective areas must necessarily lead to a different healing response. The thinner cortical plate in the canine region should be respected in this regard. Any surgical interference will necessarily cause a greater resorption of bone in the maxilla because of the anatomical difference in the bones. (Furstman and Bernick, 1972).

Sjolian and Zachrisson (1973) clearly demonstrated that bone loss in orthodontic treatment was not marked in the closed extraction spaces. It was more marked on the pressure sides following closure of the extraction space.

This finding agrees with Zachrisson and Alnaes (1974) who point out that it is the extractions which cause the bone loss rather than the orthodontic space closure, because there was a tendency to bone loss in some of the serial extraction cases of the untreated group.
DISCUSSION

Extraction leads to loss of crestal bone (Zachrisson et al., 1972; Furstman et al., 1972). Exposure and follicle removal hastens gingival recession initially (Cohen, 1962) and surgical removal is not without resorptive sequelae (Wisth, 1975; Nyman et al., 1979).

A conservative approach to surgical exposure is warranted. Minimal bone loss for exposure and attachment is required. More bone is removed with the ligation technique than for the bonding or pinning technique (Godfrey, 1981). Great care must be exercised by the surgeon when the wire lasso is tightened. The possibility of the lasso being forced in an apical direction due to conical root shape, with stripping of attachment below the cemento-enamel junction and subsequent apical exposure into the oral cavity is an ever-present danger with the wire lasso technique. There is no evidence to date regarding the expediency of creating a channel in the bone from the exposure site in the palate to the position in the arch it will occupy.

Gentle forces to move the teeth away from the roots of the anterior teeth will minimise crestal bone loss (Waerhaug, 1980) and meticulous care with oral hygiene is necessary to keep gingival health in optimal condition during the orthodontic positioning of the tooth.
2.4 SPECIFIC STUDIES

2.4.1 STUDY 1

The literature on the subject of the periodontal status of orthodontically treated palatally impacted canines is rather sparse, to say the least. The first study touching upon this topic was carried out by Hansson and Linder-Aronson in 1972.

Their study involved eighteen patients where a unilateral palatally impacted canine was exposed and brought downwards with a force of approximately 30 grams. They used as attachments pins, caps or bonded lingual buttons (surgical techniques were not described). They were examined for the occurrence of plaque, the state of the gingiva, the depths of the pockets at upper incisors, canines and premolars and the height of the marginal bone in the upper canine area. Also the mesio-distal axial inclination of the upper canines was measured. The results showed significant differences between the treated and untreated canines in the same patient with respect to the depth of the mesio-lingual gingival pockets. The gingival index (Silness and Löe, 1964) suggested a difference at the 5 percent level of significance for the mesial aspect. The bone score (difference between crestal bone heights of treated and untreated teeth) showed a similar tendency for the loss of bone at the mesial aspect and the difference was almost significant.

They concluded that bone was lost more so on the treated canines because during uprighting, bone regeneration has to take place over a longer distance. Also, bone regeneration is particularly sensitive to any inflammatory disturbance; viz. the effect of plaque due to insufficient cleansing.
They further concluded that the orthodontic treatment altered the periodontal condition to only a limited extent.

DISCUSSION

Unfortunately, plaque and gingival scores were not taken during the course of orthodontic treatment, therefore their premise that plaque contributed to bone loss is not valid. There is also no correlation between depth of pockets and factors such as age of patient, length of treatment and severity of impaction.

2.4.2 STUDY 2

The second study was carried out by Wisth, Nordeval and Boe (1976). They studied pocket depth, loss of attachment, crestal bone loss and plaque and gingival indices on 34 patients with unilateral palatal cusp impaction. No other extractions were performed save the extraction of the occasional persistent deciduous canine. The crown of the cusp was exposed without raising a mucoperiosteal flap, thereby leaving untouched the gingival areas of adjacent teeth. The cusp was pinned at its incisal tip and a traction force of 30 grams was applied in a vertical and buccal direction. They divided their patients into two groups according to the age of the patient at the start of treatment. Those younger than 15 years at the start of treatment and those older than 15 years at the start of treatment. Measurement of the gingival pocket on the treated teeth was significantly deeper than on the control tooth on the opposite side of the arch, the treated canine displayed significantly more loss of periodontal support on the buccal and palatal surfaces than did the untreated teeth.
A comparison of the mean loss of attachment on the experimental teeth in the two age groups revealed that only on the mesial surface was this loss significantly greater in the older group. Variability of attachment loss was considerably higher in the older group which means that the risk of relatively great periodontal destruction in an individual case is greater in adults. The control teeth also displayed greater attachment loss on the mesial surface in the older group and the distance from the cemento-enamel junction to crestal bone margin was considerably greater for both mesial and distal surfaces. This sustains the hypothesis that a difference in loss of attachment between the experimental and control teeth may be concealed by loss of periodontal support on the control teeth prior to treatment in the older individual. This agrees with the work of Marshall-Day and Schourie (1949) and Shei et al. (1959).

The distance from the cemento-enamel junction to the bone margin was approximately 2 mm on both the mesial and distal surfaces of the experimental teeth thus indicating a definite bone loss. On the basis of Herul's investigation and on the basis of observation in histologic sections from the normal human being, the alveolar crest was considered to be of optimum height when it was found 1 mm or less from the cemento-enamel junction (Schei et al., 1959). The measurement differed significantly from the control teeth on the mesial side which may indicate that bone loss was caused by the mesial pressure zone when canines are uprighted in a mesio-distal direction.

Variability was higher for the different registrations for the experimental teeth indicating that the risk of periodontal destruction is greater for a corrected impacted canine than its counterpart tooth serving as part of the anchorage system.
The older group showed that loss of attachment on the palatal surface was significantly greater in experimental teeth, and, in the younger group, the attachment loss on the mesial and buccal surfaces was more pronounced. The longer treatment time in the older group did not accentuate the differences between the experimental and control teeth. On the other hand, the mean loss of attachment was higher in the older group.

The distance from cemento-enamel junction to bone crest was significantly greater on both mesial and distal surfaces of the experimental teeth in the younger group, whereas only the mesial surface was affected to any extent in the older group. This may indicate that bone destruction occurred more easily in young individuals or that more bone destruction had taken place around the control teeth at the start of treatment in the older individuals and consequently some of the differences might be concealed.

DISCUSSION

The study of Wisth et al. was fairly complete, except for the fact that gingival and periodontal indices were not taken during the period of orthodontic treatment.

Also, the surgical technique used by Wisth et al. is not recommended by other workers (Clarke, 1969; Helmore, 1967) because of the danger of leaving the lingual gingiva of adjacent teeth without an adequate blood supply. This may then lead to periodontal destruction on the lingual surface of adjacent teeth. No mention is made concerning the anatomical position of eruption of the crown of the tooth. If the crown erupts well away from the gingival margin of adjacent teeth, there will be little destruction of crestal bone due to the split papilla and downgrowth of plaque referred to by Waerhaug (1980).
2.5 ANATOMICAL AND HISTOLOGICAL CONSIDERATIONS

2.5.1. POSITION OF ERUPTION

Eruption of a tooth into a crowded situation creates an irregular contact line within the interdental papilla. This results in a "split papilla" and a premature downgrowth of plaque occurs at the area of the cemento-enamel junction. (Waerhaug, 1980).

This problem is often seen with the palatally placed impacted canine. As it erupts, it is forced against the disto-lingual aspect of the lateral incisor. A split papilla results, with "premature" downgrowth of plaque. Added to this, the crown having been forced against the lateral incisor, apical to the cemento-enamel junction, causes the bone crest at this point to be resorbed. This could explain the increased pocket depth of the mesio-lingual aspect of the treated canines which Hansson et al. (1972) found. (See Fig. 12).

The buccal cortical plate of the alveolar process must be preserved. Once destroyed, the cortical plate does not have unlimited powers of remodelling, when compared with a similar operation in the mandible (Rayne, 1969; Furstman and Bernick, 1972).

The practice of radical removal of bone around a canine and subsequent maintenance of the exposure may be followed by inadequate remodelling of bone in the palate - as is the marsupialisation of a dental cyst in the palate which may be followed by deficient remodelling (Rayne, 1969). However, this is more of a problem where the canine is labially impacted, because bone removal labially will result in a deficiency if the exposure is maintained by a surgical dressing.
FIG. 12  CANINE ON RIGHT OF PICTURE SHOWING FORMATION OF SPLIT PAPILLA WITH "DOWN GROWTH OF PLAQUE".
By replacing the flap after surgical exposure, the tooth will erupt through the bone which is more natural than eruption into a defect. (Rayne, 1969).

DISCUSSION

To encourage a favourable eruption of the palatally impacted cuspid, Helmore (1967) and Clark (1971) favour the stimulation of the tooth crown so that it will erupt well clear of the roots of the approximating teeth.

Jacobý (1979) has developed the Ballista spring referred to earlier. This is an excellent device for forceful eruption of the impacted cuspid in a vertical plane so that the cuspid does not erupt into the disto-lingual aspect of the upper lateral incisor tooth, thereby creating the "split papilla" and sheared bone crest at this point. After eruption, the tooth can be moved by conventional orthodontic means to its position in the arch.

2.5.2 THE DENTO-GINGIVAL JUNCTION AND ALVEOLAR CREST

The area which is most affected by the surgical-orthodontic procedure is the alveolar crest and dento-gingival junction.

The dento-gingival junction (Gargiulo et al., 1961) is a functional unit composed of two parts:

1. The connective tissue fibrous attachment of the gingiva; and
2. The epithelial attachment which is now designated the "Junctional epithelium" (Listgarten and Schroeder, 1977).
The work of Gargiulo et al. (1961) has indicated that there is a somewhat definite proportional dimensional relation between the dento-gingival junction and the other supporting tissues of the tooth:

During passive eruption, the junctional epithelium diminishes. However, the connective tissue component appears to be a constant through the stages of passive eruption, that is, the distance from the base of the junctional epithelium to the crest of the alveolar bone is the most consistent measurement and it has a mean average length of 1.07 mm. The most variable part is the length of the junctional epithelium.

2.5.3 THE GINGIVAL CUFF

In the early stages of eruption, the crown is enclosed in a deep cuff of gingivae which is detached from the tooth to the level of any remaining enamel epithelium (see fig.13). When the tooth has fully erupted, the detached part of the cuff has been reduced to 0.5-1.0 mm which constitutes the free gingivae (see fig.13). At this stage the tooth has attained a functional position in the occlusion and the two-thirds to three-quarters of the enamel surface is exposed in the mouth. The remaining enamel is related to the gingival cuff epithelium. The accepted normal relationship for the fully erupted tooth is that the base of the cuff is in the region of the cemento-enamel junction. According to Gottlieb's (1938) theory of continuous eruption, from this stage there is a rootward shift of the cuff in the process of passive eruption, so that the cuff becomes related to the cementum.
FIG. 13

GINGIVAL CUFF

(a) Deep Cuff post eruption  (b) Complete eruption.
Gingival cuff 0 - 1.0 mm

FIG. 14

A = Histological Sulcus = Gingival Crevic
A+B = Clinical Sulcus

Adapted from McPhee & Cowley (1975)
Cohen (1965) believes that pathology must be present before epithelium migrates onto the root surface.

The latter view has been supported by a number of studies, including one of a group of Canadian Eskimos (Williams, 1943). Williams found no macroscopic increase in distance from the cemento-enamel junction to the alveolar crest even in the presence of complete crown loss through attrition.

Murphy (1959) showed, however, that there is a true continual eruption in the teeth of Stone-age man, because, if eruption ceased despite the heavy occlusal and interproximal attrition, Stone-age man's jaws would have come closer and closer together. Continual eruption occurs also in civilised man's dentition (Begg, 1956), but the consequence here due to lack of occlusal wear is that his face becomes longer as he grows older, because his teeth keep on erupting throughout life and more and more of his tooth roots become exposed.

2.5.3.1 Histological versus Clinical Sulcus

At a histologic level, the gingival sulcus is a shallow furrow approximately 0.5 mm in depth, whose base is formed by junctional epithelium (see fig. 14). Due to its structural weakness, junctional epithelium is readily disturbed either by the introduction of foreign objects such as metal, plastic or paper strips or periodontal probes, or by attempts at separating the gingiva from the tooth surface. This disruption usually occurs within the epithelium rather than at the dento-epithelial junction.

The depth of the clinical gingival sulcus may be defined as the depth past the gingival margin to which a periodontal probe will penetrate when introduced with light pressure.
Thus the histological and clinical sulcus depths are different entities which should not be confused with one another.

2.5.3.2 Crevicular Physiological Dimension

The gingival crevice extends from the free gingival margin to the junctional epithelium (see fig. 14). Normally it has a depth of 0 to 3 or 4 mm and it is lined with thin crevicular epithelium. In health, this thin fragile epithelium is in contact with the surface of the tooth (Maynard and Wilson, 1979).

2.5.3.3 Subcrevicular Physiological Dimension

This dimension is defined as the distance from the base of the gingival crevice to the alveolar crest and includes the junctional epithelium and the supra-alveolar connective tissue fibres (see fig. 14).

Gargiulo, Wentz and Orban (1961) described this dimension. It varies in width because of variations in width of the supra-alveolar connective tissue fibres. The connective tissue component appears to remain constant through the stage of passive eruption. These authors found the average measurement of the epithelial attachment to be 0.97 mm with a range of 0.71 to 1.35 mm. The connective tissue fibre attachment had an average measurement of 1.07 mm with a range of 1.06 to 1.08 mm.

2.5.3.4 Adaptation of the cuff to the Tooth

The seal between the crown environment and the root environment is dependant on the continuity of the epithelial sheath as a whole and particularly on the degree of adaptation of the gingival cuff to the tooth.
Factors which may influence the relationship of the cuff epithelium to the tooth are:

1. The products of the superficial cells of the cuff epithelium may contribute to a cuticle on the tooth surface to which the cells themselves adhere. The factors concerned with the stickiness of cells and adhesion of epithelium have been reviewed by Schultz-Haudt et al. (1963).

2. The condition of the gel structure of the surrounding gingival connective tissue is governed partly by the central factors controlling local tissue metabolism and partly by the constantly changing crown environment.

3. Connective tissue is a dynamic structure and there is a constant exchange of soluble collagen between the connective tissue bundles and the ground substance. The degree of condensation into fibres is variable, and it is governed by a wide range of factors such as the degree of function of the teeth, or the presence of tissue intoxicating factors.

2.5.3.5 Marginal Ligament

The ligament consists of a well defined condensation of collagen fibres which circumscribes the teeth. (McPhee and Cowley, 1975). For practical purposes, it may be visualised as a figure of eight weave of collagen bundles having a highly specialised arrangement in the region of the embrasure (see fig. 16).

In this region, five groups of fibres have been said to contribute to maintaining the relationship of the epithelial cuff to the tooth (see fig. 17).
FIG. 15
THE MARGINAL LIGAMENT

FIG. 16 CIRCULAR FIBRES OF THE MARGINAL LIGAMENT

FIG. 17 SUPRA-CRESTAL FIBRES

(a) & (b) Dento-gingival fibres
(c) Free gingival fibres
(d) Circular fibres
(e) Transeptal fibres
(f) Dento-periosteal fibres
These are dentogingival fibres which attach the gingival tissue to cementum; free gingival fibres which attach gingival tissue to bone; circular fibres which circumscribe the tooth; transeptal fibres which cross the embrasure from tooth coronal to the alveolar crest; dento-periosteal fibres which course from the cementum to the periostium of the alveolar crest.

Disruption of this anatomical arrangement of the connective tissues and the loss of continuity of the buccal and lingual papillae through the embrasure are the first major signs of an established periodontitis (Melcher, 1962).

It is hypothesised that the periodontal health of the orthodontically treated palatal canine is dependant on the re-establishment of the marginal ligament which may take some time to consolidate properly after orthodontic treatment has ceased.

Attachment loss should be assessed some time after orthodontic treatment has finished and during the retention period meticulous attention should be paid to oral hygiene to prevent any untoward effect by retained plaque in the gingival crevice which may impede the re-establishment of these supra-crestal fibres.

2.5.4 THE CANINE EMINENCE

By definition the canine eminence is the prominence on the labial aspect of the maxilla overlying the root of the canine tooth (Henns, 1974). Dewel (1949), referring to the upper cuspid, stated: "Aesthetically its strategic position at the angle of the arch is significant in maintenance of harmony and symmetry of occlusal relationship, and in determining the contours of the mouth as a whole."
Sicher (1949) stated: "The compactness and the size of the cuspid roots cause an even greater bulging of the socket toward the alveolar process and the alveolar eminence of the canine tooth is the most prominent in the upper jaw."

Wheeler (1940) writes: "Both maxillary and mandibular canines have another quality which must not be overlooked. The positions and forms of these teeth and their anchorage in the bone, with the bony ridge over the labial positions of the roots, called the "Canine eminence", have a cosmetic value. With their roots, they help to form a foundation that ensures normal facial expression at the corners of the mouth."

At the age of eight years, it is usually possible to palpate the bulge of the crown of the canine high in the labial sulcus above the root of the deciduous canine root of the deciduous canine. If a periapical film at this age does not show resorption of the deciduous canine root, repeated six monthly films will show when normal resorption is established or interceptive measures are indicated (Rayne, 1969).

The following illustration will show that the canine eminence is not present till the crown has begun to resorb the root of the deciduous tooth, because the crown is located lingual to the apex of the deciduous tooth. (Fig. 19).

O'Meara and Knott (1967) in a study on primary canine root resorption found that the median age at initial root resorption for the maxillary deciduous canine was 8.8 years in boys and 7.9 years in girls, and 90 percent of the children showed complete.
FIG. 18
POSITION OF CUSPID AT AGE 1

This tracing at the age of 1 year shows the beginning of calcification of the permanent cuspid between the roots of the first deciduous molars

From Dewel (1949)

FIG. 19
POSITION OF CUSPID AT AGE 7

From Dewel (1949)
resorption in four years (50 percent had complete resorption in two years). Therefore, absence of a canine bulge by the age of nine years should alert us to the possibility of the permanent canine not erupting normally. This study is in agreement with the clinical observation of Rayne (1969).

Henns (1974) studied the canine eminence to ascertain change in its position when the canine tooth was orthodontically moved to the position of the lateral incisor. Henns used pantographic tracings of the buccal surface of plaster models: the tracings were done 3 mm above the highest point of the gingival crevice of the central incisors. The 3 mm height chosen for the recordings showed the greatest bulge of the canine eminence of the casts used in this study. The tracings were started and terminated above the mesial cusp tip of each first permanent molar. The first group of 52 treated cases had cuspids as lateral incisors, average age 15 years 9 months. The second group consisted of 52 treated Class I premolar extraction cases, average age 15 years 2 months. The pantographic tracings of the missing lateral incisor group and the Class I extraction group were all superimposed in their two separate categories. These were superimposed on the midpalatal line and registered at the apex of the arch from where the pantograph had originally contacted the anterior surface of the individual cast.

The groupings of these lines for each of the two subject categories were then divided with calipers at their distal legs into three equal areas. The median for each of the thirds was referred to as 'A' (outer third), 'B' (middle third) and 'C' (inner third).
The 'A' median of the missing lateral incisor group was superimposed on the 'A' median of the Class I extraction tracing. The same procedure for median 'B' and median 'C' was followed.

The results showed a relatively even distribution of the recordings between the middle third of the largest and the smallest arch forms of each group. When similar medians for each group were superimposed, the greatest distance between each arch form recording was less than 1.5 mm.

Henns concluded that the canine eminence is lost from its normal position when the canine is used as a lateral and that the resulting change in arch form as a result of this shift has been overemphasised.

This showed also that a canine eminence can be created by tooth movement, a feat which is also possible when an impacted maxillary canine is moved labially into its position in the arch.

2.5.5. GROWTH OF ALVEOLAR BONE

Enlow and co-workers (1980) studied surface remodelling of the maxilla and mandible in the early and mixed dentition. They noted that there was a generalised resorptive activity on the anterior surface of the maxilla. In the late primary dentition, this extends inferiorly but does not include the alveolar crest. In the mixed dentition, there is rapid growth at the occlusal crest in relation to tooth eruption and vertical drifting of teeth. Thin small spot deposits of periosteal lamellar bone continue to provide cover on localised surface bulges overlying protruding roots on crowns of erupting teeth.
This provides the basis of the canine eminence formation. The canine eminence thus develops as a response to the erupting canine.

The age limit of surface deposition is not revealed in this study. However, the oldest specimen studied in this series (14 years) showed generalised surface resorption anteriorly and deposition at the alveolar crest near the second molar and tuberosity region.

The upper limits of surface deposition in the canine region, therefore, appear not to be beyond the age of 14 years. However, surface resorption between the roots of the teeth may create a bulge over the tooth roots, thus helping to create an eminence.

To ensure the correct canine eminence is restored, labial root movement may be necessary. However, fine clinical judgement should be exercised in the older patient where labial bone is deficient and labial root movement might cause iatrogenic fenestration or dehiscence of the labial plate of bone. The nature of these defects will be briefly discussed.

2.5.6 GROWTH DEFECTS OF THE ALVEOLUS

Scott (1968) writes about the alveolar bone which is pertinent to our study: "In modern man, the predominant direction of alveolar bone growth is vertical with a limited and variable amount of forward and outward growth."

"In the growth of the alveolar process, the outer alveolar plate, especially in the upper jaw is liable, as a consequence of a breakdown in the balance between bone deposition and bone
resorption, to become incomplete, leading to varying degrees of 
failure of tooth support, and what is perhaps more important, failure 
of support for overlying gum tissue. The same condition can also 
occur as a result of orthodontic treatment in which the integrity of 
the supporting tissue is sacrificed to the mechanical purpose of 
moving teeth."

Scott also refers to the presence of window-like openings on 
the buccal surfaces of the alveolar process, exposing areas of the 
roots of the teeth, most frequently found in relation to the upper 
cheek teeth. This represents a characteristic human tendency toward 
a lack of adequate bone formation in relation to the migrating den-
tition perhaps accentuated in older skulls by a generalised bone 
resorption. These defects have been referred to as "fenestration" 
and "dehiscences".

Fenestration: From the Latin "fenestra" - window.

Dehiscence: From the Latin "dehiscere": "de" - from 
and "hiscere" - be open, gape. (pronounced 
dihisens)

Fenestrations are window-like openings over the roots of permanent 
teeth. There is a thin layer of bone coronal to the opening. A 
dehiscence is the result of bone loss labially, exceeding one half 
the root length, resulting in a denuded root surface.

In a study of alveolar defects, Elliott and Bowers (1963) 
detected in a series of human skulls, an incidence of 20 percent 
which had these types of alveolar defects. They observed:

1. That defects were most frequently found in regions where 
the anatomical shapes and positionings of the teeth resulted 
in a thin covering of alveolar bone proper and cortical 
plate.
2. Osseous resorption following muco-gingival surgery may occur resulting in a surgically produced dehiscence.

Where there has been prolonged absence of the deciduous canine, there will be absence of the normal canine eminence in the case of the palatally displaced canine.

Surgical exposure and orthodontic movement of the canine to its proper position and root torque against a thin cortical plate could conceivably bring about the formation of an alveolar defect such as fenestration or dehiscence.

Picton (1969) in his observations of North American Indian skulls showed a complete alveolus is not necessary for normal tooth support. Dehiscences and fenestrations were common in the labial walls of these skulls.

Although compression within the periodontal ligament may be important in tooth support, the effect must be localised to restricted areas of the alveolus. However, tension would not seem to be hampered by an incomplete alveolus.

2.5.6.1 Diagnosis of Fenestration and Dehiscence

The anatomical situation of the alveolar fenestration presents a problem in diagnosis. Lack of subjective symptoms and the difficulty in depicting the lesion on a radiograph makes diagnosis very difficult (Elliott and Bowers, 1963). They further state: "Of diagnostic significance is that teeth which are set off basal bone or possess roots that bulge through the cortical plate are frequently devoid of facial bone."
The remaining edges of bone present an osseous periphery of tissue paper thickness. Fenestrations are actually a stage in the development of a dehiscence, a stage that could be accelerated by muco-gingival surgery."

The clinical signs of a dehiscence present no problem in diagnosis. These signs are all too apparent because the root may be denuded from one half to two-thirds of its root length with the consequence of root hypersensitivity and problems with oral hygiene.

2.5.7 DISCUSSION

Gingival recession is the result of the loss of crestal bone.

Inflammation limited to the marginal gingiva will destroy marginal bone if the bone is thin. Areas of inflammation over the roots of teeth covered with thin bone can develop narrow pockets rapidly, almost to the apex, often without lateral extension into the interproximal or interradicular regions. These deep narrow pockets are usually associated with root fenestration or dehiscence (Prichard, 1966)

That alveolar bone will follow the (forced) eruption of the impacted maxillary canine is not disputed (Furstman et al., 1972). Loss of alveolar bone due to surgery, surgical trauma or simply plaque induced periodontitis, or by orthodontic movement is the long term problem associated with the orthodontic treatment of the impacted maxillary canine.

Recent work done by Goldman and Smukler (1978) and Passanezi et al. (1979) on the periosteal activation associated with the sliding flap operation for denuded roots shows much promise in treatment of the treated impacted canine, and the technique could be utilised to
stimulate new bone formation where this is found wanting after orthodontic treatment of the impacted maxillary canine.

To be successful, Goldman and Smukler suggest that there be sufficient interproximal alveolar bone, where a pre-stimulated sliding flap operation is contemplated. A problem with the orthodontically treated impacted canine is loss of bone interproximally.

2.5.8 CONCLUSIONS

To preserve bone around the treated canine, it is suggested:

1. To minimise labial cortical bone removal where surgical exposure is carried out.

2. To allow or cause eruption of the canine well clear of the roots and gingival margins of adjacent teeth in a vertical direction initially.

3. Institute strict oral hygiene measures during the course of treatment.

The use of a small circular tufted brush together with a 'Water-Pik' device would be most helpful in keeping the erupting tooth and traction appliance free from plaque and food debris - thus minimising the irritating effect of plaque on the attachments (Hugoson, 1978).

4. Avoid over-torquing of the canine to minimise the possibility of producing a fenestration or dehiscence.
PART 3

ASSESSMENT OF PERIODONTAL

HEALTH AND CRESTAL BONE HEIGHT
3. ASSESSMENT OF PERIODONTAL HEALTH AND CRESTAL BONE HEIGHT

3.1 RADIOGRAPHIC ASSESSMENT OF BONE HEIGHT

Introduction

In this study, we shall consider if radiographs can show bone levels accurately and whether they can be measured accurately.

The criteria of accuracy advocated by Prichard (1965) have been used by workers such as Rees et al. (1971) for determining the acceptability of radiographs. These criteria are as follows:

1. Tips of molar cusps will show little or none of the occlusal surface.
2. Distinct enamel caps.
3. Open interproximal spaces.
4. Proximal contacts that do not overlap unless teeth are out of line anatomically.

The long cone paralleling method (Updegrave, 1951) is favoured by many workers in the field of periodontal research (Fixott, 1957; Dunning and Leach, 1968; Suomi et al., 1968) who claim that the long cone method produces the most accurate radiographs with minimal magnification and least distortion.

Using re-entry techniques, Robinson (1969), Schallorn et al. (1970) and Rosenberg (1971) claim that radiographs have the ability to assess accurately the outcome of surgery.
The problem statement is: Using the long cone paralleling technique (Updegrave, 1951), can we accurately measure the crestal bone height of the maxillary canine tooth, and by comparison with the same tooth on the opposite side of the arch, determine the amount of crestal bone loss which the orthodontically treated maxillary impacted canine has suffered as a result of surgery, orthodontic treatment or other factors such as increased plaque retention during treatment, as outlined earlier in this thesis?

3.1.1 CRITERIA OF RADIOGRAPHIC EVIDENCE OF CRESTAL BONE LOSS

There is some agreement as to the descriptive radiographic appearance of the alveolar bone where there is periodontal bone loss: Hull et al. (1975), Blankenstein et al. (1978) followed these criteria in their assessment of bone loss.

1. Irregularity and 'notching' of the alveolar crest.

2. Increased linear distance between cemento-enamel junction and bone crest.

3. Widening of the periodontal ligament space at its alveolar crest.

One radiographically measurable criterion is the cemento-enamel junction to the bone crest distance. Controversy exists as to the distance which constitutes bone loss in this area.

Gargiulo et al (1961) defined the dimensions of dento-gingival junction in humans and in 'Phase 1' of tooth eruption they claim that the mean average distance from cemento-enamel junction to alveolar bone is 1.08 mm.
The average age of these 'Phase 1' specimens was 24.5 years.

Belting, Massler and Schour (1953) considered pathological bone loss to have taken place when alveolar crest was 2mm or more from cemento-enamel junction.

Schei et al. (1959) in their study on males 21-45 years considered optimal bone height as 1 mm or less from the cemento-enamel junction. This figure basically agrees with Hollender et al. (1966) who considered the alveolar crest to cemento-enamel junction distance as 1-1.5 mm in 13 and 14 year old school children.

Hull et al. (1975) uses the figure of 1.5 mm from alveolar crest to cemento-enamel junction as the optimal height in 13-15 year old school children.

Where a tooth is compared with its homologous control tooth in the same mouth, the control tooth is regarded as having normal bone height and precise measurements as a base line need not be used. This principle was used by Gilmore and Sheiham (1971) when they studied bone height relations to overhanging restorations, and compared them with the unrestored homologous tooth. Any evidence of bone height difference further than that existing on the control tooth can be presumed to be the result of periodontal pathology, surgical interference, plaque-induced, or other iatrogenic cause.

The method of Gilmore and Sheiham (1971) lends itself to this study where the control tooth (untreated canine) is compared to the treated impacted maxillary canine. Because of the difficulty in depicting the root apex of the canine tooth the bone crest will be assessed in relation to the cemento-enamel junction as this distance has been found to be relatively consistent (Gargiulo et al., 1961).
3.1.2 RELIABILITY OF X-RAYS IN REPRODUCING BONE HEIGHT

3.1.2.1 Ability of radiographs to accurately depict bone loss

In any attempt to equate a radiographic study with a clinical situation, the correlation between radiographic and clinical measurements must be considered. Suomi, Plombo and Barbano (1968) evaluated osseous defects associated with periodontal disease both radiographically and at the time of surgical flap reflection. They found that the clinical measurement averaged 1.04 mm greater than the radiographic measurement. Lundquist, Levin and Johanson (1955) found that with standardisation of the radiographic technique, the measurement of alveolar crest height was the most accurate of several measurements taken from the radiograph.

Early bone loss is difficult to depict in radiographs (Hollender et al., 1966; Ramadan and Mitchell, 1962; and Ainamo, Tamisalo, 1973).

Hull et al. (1975), however, found radiographic evidence of early bone loss in 14 year old school children and estimated that 50 percent of the children had at least one area of alveolar crest showing bone loss. At this early age it is necessary to distinguish between changes in bone configuration associated with tooth eruption and bone loss due to chronic periodontitis. The key to this question is the regularity of the crestal bone and its close relation to the cemento-enamel junction. Several investigations have been carried out in order to determine the amount of bone resorption which can be visualised in radiographs.
Lesions produced with burs in dried specimens of cancellous bone were not visible in radiographs unless the cortical bone plates had been eroded extensively or penetrated (Bender and Seltzer, 1961a, b; Wengraf A, 1964). Likewise, Ramadan and Mitchell (1962) found that interproximal defects produced in dried human skulls could not be seen in radiographs when the buccal and lingual cortical plates were intact. Defects on the buccal and lingual root surfaces could only be seen if the cortical plate was thick and a high degree of contrast existed between the defect and surrounding bone.

Septal defects were created experimentally by Pauls and Trotts (1966) and were noticed radiographically only if they had a minimum depth of 3 mm.

Due to the lack of separate buccal and lingual visualisation of the alveolar crest, the amount of bone loss is generally underestimated (Theilade, 1960a,b). The interpretation of vertical bone destruction on the buccal and lingual aspects of the jaw is impaired by superposition of the tooth and therefore cannot be assessed accurately on the radiograph (Patur and Glickman, 1962; Rees et al., 1971). The visualisation of interproximal intra-bony defects can only be determined by surgical exposure (Prichard, 1961, 1966).

Barium and Lipiodol penetrations have been used to discover the bony topography of periodontal pockets (Berry, 1951). Insertion of calibrated silver points into the pocket prior to exposing the x-ray film is useful to evaluate intra-bony pockets and to locate fistulous tracts and periodontal abscesses in relation to teeth.
The points were developed by Hirschfield (1952) and have been improved upon by Baumhammers and Ceravolo (1977) who called this instrument the 'Pitt Point'.

In order to visualise three dimensional changes in alveolar crest height, a stereoscopic technique was introduced (Berghagen and Blom, 1961). Two films of the same subject were exposed with different horizontal angulations and the radiographs were observed with stereoscopic viewers. Superimposed detail may be distinguished and definition improved with this technique.

3.1.2.2 Accuracy of measurements using the radiograph

Stoner (1972) made direct measurements of posterior alveolar crests on dried skulls and compared them with the measurement of the radiographic image. Comparisons showed that a dimensionally accurate radiographic image could be obtained because the measurements were equal or different by 1 mm in 87.5 percent of measurements.

Suomi et al. (1968), using the long-cone technique (Updegrave, 1961), determined the bone height on the basis of radiographic measurements. Probing prior to and after surgical exposure of the alveolar bone they demonstrated that there was no significant difference between radiographic and clinical measurements. These results indicate that radiographs are useful for an accurate evaluation of the level of alveolar bone, but that clinical measurements of the attachment level yield an equally accurate assessment of the periodontal destruction.
Lundquist, Levin and Johansen (1955-56) used a standardised technique to measure the alveolar crest height radiographically. They found that the measurement of the alveolar crest was the most accurate of several measurements taken from the radiograph.

Boyle et al. (1973) using the long-cone technique with the x-ray beam at right angles to the tooth and the film, with a fixed tooth-film distance, produced films from which consistent measurements of the alveolar crest height could be made. The measurement variation was well within clinically acceptable limits.

Brown and Owings (1975) described a reproducible method of evaluating radiographic changes in periodontal disease. They used the long-cone technique (Updegrave, 1961) and a millimetre grid superimposed on the film. They utilised endosseous implants near the apex of the tooth, and amalgam markers placed on the crown of the tooth as fixed reference points from which to interpret the diagnostic radiographs. Calibrated radio-opaque markers were placed in the periodontal pockets down to bone contact under local anaesthesia. The results showed only a small degree of variability between the different measurements. Ninety-five percent of the time the placement of the pocket marker varied only 0.28 mm from the exact depth of the lesion. They also showed that measurements from only the amalgam marker reference point were just as accurate as measurements from the implant.

Kelly et al. (1975) evaluated the applicability of the long-cone technique in clinical trials of periodontal treatment. They found that attachment levels assessed by probing and inter-proximal bone height measurements assessed by the method of Björn et al. (1969)
correlated with a high degree of statistical significance both before and after periodontal therapy and that longitudinal interproximal changes in periodontal support as measured by probing and by the Björn et al. (1969b) radiographic method are related.

2.1.3 INTERPRETATION OF RADIOGRAPH

The presence or absence of a lamina dura on radiographs may be affected by slight variations in the angulation of the x-ray beam. The convexity or concavity of proximal tooth surfaces, the curvature of the roots, the level of the cemento-enamel junction and the thickness of the alveolar bone may cause variations in the thickness and clarity of the lamina dura. (Ritchey and Orban, 1952; Manson, 1963).

With teeth that have a broad bucco-lingual width, or elliptical shaped roots, the x-ray beam must penetrate through a great amount of hard tissue before it reaches the film. Therefore, the lamina dura around such teeth will appear radiographically very dense. The lamina dura also follows the topography of the cemento-enamel junction which may give the appearance of angular bone defects if the teeth are tilted (Ritchey and Orban, 1953). Changes in the horizontal and vertical angulation may also affect the thickness of the periodontal membrane space. A widened periodontal membrane space may be due to variation in the radius of the root curvature or the result of increased voltage or exposure time. (Van Der Linden and Van Aken, 1970). Therefore, two teeth with roots of different size and curvature but surrounded by a periodontal membrane of the same size may in fact, in the radiograph, show periodontal membrane spaces of which one is twice as wide as the other.
Furthermore, multiple lines may occur at the image of the periodontal membrane space of teeth with concave roots. The membrane of these lines varies according to the depth of the concavity and the width of the periodontal membrane (Van Der Linden and Van Aken, 1970).

Stoner (1972) reports that alveolar crests with resorption confined to their centres showed a subcrestal radiolucent image on the radiographs and a normal crestal outline. To gain maximum definition of the alveolar crest, Stoner recommends the under-exposure of the film.

In 1939 Miller and Pelzer attempted to develop a guide for predicting the rate of progress of periodontal disease based on the conformity of density of alveolar bone as revealed by the radiograph. They believed that the rapidity of bone destruction was inversely proportional to the density of alveolar bone. They noted that the absence of lamina dura indicated the presence of osseous disease changes.

Barr in 1961 stated that the density of bone on a radiograph depended upon the density of tissues overlying the bone. He recommended serial radiographs before he could diagnose periodontal change.

Orban (1963) stated that the lamina dura visible on dental radiographs represented the thin cortical bone which covered alveolar crests and lined tooth sockets. He believed it to be more densely calcified than other cortical bone and that a break in the continuity of the lamina dura was evidence of a developing disease process.
Goldman, Millsap and Berman (1937) obtained radiographs of block sections of alveolar bone and concluded that the lamina dura was no more dense than other cortical bone. Rather, the shape of the tooth socket which resulted in x-rays passing through the width of cortical bone on the proximal surfaces of teeth, caused these areas to appear more radiopaque.

Manson (1963) supported Goldman's findings. In micro-radiographic studies of alveolar bone, he found no evidence of a high density band of bone corresponding to the lamina dura. He concluded that variations in appearance of the lamina dura should not determine the diagnosis of periodontal or periapical disease.

3.1.4 RADIOGRAPHIC TECHNIQUES

3.1.4.1 Projection technique

There are two basic techniques used to radiograph the teeth. One is commonly known as 'bisection-angle' technique. This technique is based on the principle of positioning the film as close to the lingual surfaces of the teeth as possible and then directing the x-ray beam perpendicular to an imaginary plane which bisects the angle formed by the long axes of the teeth and the plane of the film. The focal-film (cone) distance for this technique can be as short as five inches or as long as the operator chooses.

The other technique is commonly known as the long-cone paralleling or right angle technique (Updegrave, 1951) and is based on the principle of positioning the film as parallel with the long
axis of the teeth as the anatomy will permit, regardless of the distance created between the film and the teeth. The x-ray beam is then directed perpendicularly to the film. Since paralleling the film with the teeth results in an increase in the distance between the two, this will produce an enlarged and indistinct image if the short cone is used. Updegrave (1968) recommends doubling the focal-film distance to overcome undesirable results and substituting a 16 inch extension tube for the conventional 8 inch short cone on the x-ray unit as the most practical way of producing optimal results.

Prichard (1966) has stated that an accurate radiographic orientation of the cemento-enamel junction to the alveolar crest is dependent upon correct vertical and horizontal cone angulation. To attain dimensionally accurate radiographs, numerous investigators such as Dunning and Leach (1968), Fixott (1957), Updegrave (1961), Ramadan and Mitchell (1962) and Suomi et al. (1968) have compared different techniques and concluded that the bite-wing radiograph or the long-cone (16 inches or more target-to-film distance) and the paralleling techniques are superior to any other technique.

3.1.4.2 Errors in Projection

Harndt (1958) claims that errors of projection are more likely to result in distortions in the marginal than in the apical areas of the alveolar bone because the delicate edges of the crest are difficult to radiograph.

In the study at hand, owing to the anatomical features of the mouth, it is found in practice that it is quite often difficult to apply the paralleling technique correctly and some compromises have to be made (Silha, 1968).
3.1.4.3 Influence of Varying Angulation

Björn (1969, a & b) found slight and not significant differences in bone score values when the tube angulation is varied through a small angle (+10 percent). Prichard (1968) claims that accurate orientation of the cemento-enamel junction to the inter-alveolar crest depends on the correct vertical and horizontal angulation. The parallel technique of x-ray projection will give repeated radiographs that are highly accurate.

3.1.4.4 Errors of exposure and processing of film

Rosling et al. (1975) claim that variation in exposure of the film is an important source of error. A long focus-film distance implies an exposure time of one second or more even when ultra-speed films are used. This would imply that the effect of deficiencies in the electronic timer and voltage variations of high frequency would be negligible but it would not rule out voltage variations in the mains low frequency.

Boyle et al. (1973) recommend the processing of film from clinical studies to be completed en masse so that solution strengths and temperature do not vary. A standardised developing technique is most essential in a study such as this, although they found that film storage will not alter the film quality and that processing of film in solutions of varying strengths which are of clinically acceptable type, does not appreciably alter the film quality or the measurements taken from the film.

Prichard (1966) states that radiographs made with high kilovoltage have a long scale contrast and appear dull by comparison
with those made with 65 KVP and 10 ma., but they have improved character for interpretation. Bone is not as dense as metal, and can be recorded accurately with low voltage or properly exposed and processed films. However, osseous defects have been overlooked with the low kilovoltage exposures. Bone in unusually wide dental arches requires the greater penetration of high kilovoltage for accuracy.

3.1.5 RADIOGRAPHS IN EVALUATION OF PERIODONTAL THERAPY AND IN EPIDEMIOLOGICAL RESEARCH

3.1.5.1 Standardisation of Radiographs

Results of periodontal therapy or bone changes as a result of treatment may be incorrectly evaluated as successful if the pre-operative x-ray is under-angulated or over-exposed compared with that of the post-operative film (Wuerhmann, 1957). Serial devices have been suggested in order to standardise pre- and post-operative radiographs.

Obviously the technical specification of the film and its exposure and processing have to be the same.

One of the first devices for identical exposures was designed by Benkow in 1956. This system consisted of a tray containing a thermo-plastic compound impression of the occlusal surfaces in the area to be radiographed.
The film was placed in a tray perpendicular to a steel bar which was parallel to the x-ray beam.

The bar also ensured an identical distance between the film plane and the cone of the x-ray machine. Using the same compound impression for the pre- and post-operative exposures, it was possible to obtain identical pictures. Similar devices have been constructed by Benkow (1960 and 1970), Medwedeff et al. (1962), Dalitz (1964), Gilbers and Hannan (1968) and Puckett (1968). Rosling et al. (1975) presented a similar device which consisted of an acrylic occlusal splint with five quadrangular metal tubes attached to the splint. A metal rod connecting the splint with the x-ray cone can be inserted into the quadrangular tubes which consistently locates the cone of the x-ray. The splint has five paired tracks on the oval surface serving as film holders to allow ortho-radial projection of either the premolar or incisor region. Alterations in the marginal bone level in the radiograph were determined in a stereo comparator system.

This method involves a high degree of reproducibility of the radiographs. They tested the precision of the method and their results suggested there were negligible deviations of the elements of orientation, which were related to the small errors inherent in the method. The change in bone height could be regarded as a reliable measure of actual bone loss, and could be reliably measured by the technique as described by Björn et al. (1969b).

Schei et al. (1959) in their study on bone loss as related to age and oral hygiene, tested the influence of the angulation of the x-ray beam on the measurement of crestal bone height.
A number of x-rays were taken with an angulation of 10 degrees more and 10 degrees less than the standard type. They found that altering the angulation to this extent had little effect on the measurements in the anterior region, but the measurements in the posterior regions were altered by up to 20 percent.

3.1.5.2 Accuracy, reproducibility in measurement of alveolar bone height in radiographs

Ramfjord (1974) reviewed the methods of radiographic evaluation of periodontal support and concluded that most of the measurements could be obtained almost as accurately from parallel technique long-cone radiographs as from the use of the various positioning devices.

In spite of the obvious sources of errors in estimation of alveolar crest height from radiographs as explained by Theilade (1960), it appears that radiographs taken with various devices for reproduction of angulations and even with conventional long-cone paralleling techniques may provide more accurately reproducible results than previously anticipated. Even the Schei method (1959) has been found to have a rather low standard deviation resulting from inaccuracy of reading of 1.78 (=\sqrt{3.18}) for one investigation and 2.18 (=\sqrt{4.78}) for another (Medwedeff, 1967).

3.1.6 QUANTITATION OF BONE LOSS

3.1.6.1 Radiographic assessment of bone height

In assessing the bone height on the film, Björn (1969b) suggests using the point where the periodontal space retains its
normal width, as the alveolar bone height. Bassiouney and Grant (1975) used the method established by Engelberg et al. (1963) of using the most apically advanced translucency.

Kelly et al. (1975) modified the method of Björn to include the level of intact lamina dura as the alveolar bone height because of the work of Van Der Linden and Van Aken (1970) who showed the radiographic image of the marginal aspect of the periodontal ligament varied greatly with the horizontal angulation of the x-ray beam.

Theilade (1960) found difficulty in determining the peak of the alveolar crest when the crest had been marked by wire ligatures. Added to this he found the cemento-enamel junction cannot be represented by a well defined point.

Schei (1959) had a 25 percent non-measureability rate due to overlapping of teeth and difficulty in assessing the alveolar crest and cemento-enamel junction, and Björn et al. (1969b) had a 50 percent non-measureability rate for the distal side of maxillary canines.

The criterion of Björn (1961b) of using the point where the periodontal space retains its normal width is not a valid one in this study, particularly where orthodontic treatment had recently been completed. In these cases the periodontal membrane is still thickened in the coronal third of the root, and in these cases the crest height is determined on the most coronal part of the visible crest.
3.1.6.2 Measurement

Since measurements on radiographs require more time, equipment and money, it is reasonable to assess periodontal destruction in clinical trials on the basis of clinical attachment levels measurements. (Ramfjord, 1959; Glavind and Løe, 1967). However, several attempts have been made to determine objectively the amount of bone loss in advanced cases of periodontal disease.

One of the first methods was developed by Schei et al. (1959) who determined the percentage of alveolar bone on either the mesial or distal surface of a tooth. Using a plastic ruler, they assessed the bone height relative to the distance between the apex of the root and the normal level of the alveolar crest defined as 1 mm apical to the cemento-enamel junction.

Schei et al. developed the system used by Marshall-Day and Shourie (1949) who measured the bone loss in percentage of bone height. Crestal bone height could be assessed with an accuracy of 1 in 20. The method produced a high degree of non-measureability (25 percent) due to overlapping of teeth and difficulty in assessing the cemento-enamel junction. A number of radiographs were taken with an angulation of 10 degrees more or 10 degrees less than the standard type and they noted that the variation in angulation gave little difference in the anterior region but up to 20 percent difference in the posterior region.

Gilmore and Sheiham (1971) used Schei's ruler to estimate alveolar crest to apex in one-tenths of tooth length and also alveolar crest to crown tip in one-tenths of tooth length. These measurements were carried out on routine periapical x-rays.
Bite-wing x-rays were also used and the measurement of bone crest to crown tip was measured with a millimetre ruler. Gilmore and Sheiham (1971) compared the measurements by these two methods and when the ratio of average difference in bone heights by the "tenths of tooth length" and the "millimetre" method was used to estimate the average tooth length, the length computed (27.1 mm) did not differ markedly from the average tooth length figure of 24.4 mm for the same teeth used in the present study as reported by Black (1902). The similarity of the estimation indicates that the tenths and millimetre methods are equivocal, and that the method of measurement used in this study did not underestimate bone height.

3.1.6.3 Conclusions

1. Radiographic assessment compares favourably with direct measurements such as those used in surgical re-entry techniques.


3. Single exposure is adequate provided due regard is paid to careful film placement so that overlap with premolar or lateral incisor is minimised.

4. Single exposures are preferable in order to minimise radiation dosage which in the long-cone technique is four times the exposure time of a routine periapical radiograph using the short-cone technique.

5. Radiographic assessment is limited to interproximal bone. Buccal and lingual levels cannot be determined.
6. Using a well controlled technique, obvious sources of error such as variation in angulation, exposure and film-focus distance, may be significantly reduced.

7. The method of Gilmore and Sheiham (1971) of direct measurement compares favourably with the method of Björn (1968) and is used by the author in this study.
3.2 CLINICAL ASSESSMENT OF PERIODONTAL HEALTH

INTRODUCTION

The purpose of this section is to look at the various methods of assessing the health of the periodontium. As we have noted in the literature review of this thesis, it is the effect of plaque retained by appliances which affects the gingival health, rather than the presence of appliance itself. It is necessary to assess plaque prior to assessment of gingival inflammation, because plaque in this instance will have an additional effect over and above the primary effect on the periodontium, which is the surgical and/or orthodontic treatment.

Surgery and orthodontic treatment may affect the gingival tissues in such a way that plaque retention is increased, thereby leading to increased gingival inflammation. If plaque is not the implicating factor in a deterioration of gingival health, then we may surmise that it is these primary factors mentioned previously which are the cause of the deterioration in gingival health.

Periodontal assessments include the qualitative appearance of the gingival tissues, the pocket depth and attachment loss, and finally the assessment of the height of the alveolar crest in relation to the cemento-enamel junction. We shall deal first with plaque and gingival assessment because these are measured by ordinal parameters or 'indices' of severity. According to Davies (1968), indices of periodontal disease are measurements which express numerically the status of a group of teeth with respect to the disease.
They can also be used to measure the severity of a disease ranging from its absence to its terminal stages.

3.2.1 REQUIREMENTS OF AN INDEX

The requirements for an index have been summarised by Hazen (1974):

(a) It should be simple to use and should permit the study of a large number of persons in a minimum time and at minimum cost.

(b) The criteria should be clear and readily understandable to promote diagnostic reproducibility both within and between examiners.

(c) It should indicate in a meaningful way the clinical stages of the disease process and it should be equally sensitive throughout the range.

(d) The index should be amenable to statistical analysis.

3.2.2 INDICES OF GINGIVAL INFLAMMATION

Descriptive indices do not lend themselves to statistical analysis and 'present' or 'absent' indices do not consider severity of gingival inflammation. Numerical indices which approach the criteria as outlined by Hazen (1974) are listed below:

(a) Schour and Massler's P.M.A. Index (1949) \( \{P \text{ - Papillary} \) \\
\( \text{M - Marginal Gingiva} \) \\
\( \text{A - Attached} \) \)}
(b) Russell's Periodontal Index (1956)
(c) Muhlemann and Mazor's Sulcus Bleeding Index (1958)
(d) Ramfjord's Periodontal Disease Index (1959)
(e) Löe and Silness' Gingival Index (1963)
(f) The D.H.C. Index of Suomi et al. (1970)

The indices listed have been extensively reviewed by Hazen (1974). Hazen feels that the indices of Löe and Silness (1963) and Suomi et al. (1958) come closest to the requirements listed earlier.

The main purpose of creating the Gingival Index System (Löe and Silness, 1963) was to introduce a system for the assessment of the condition which clearly distinguished between the quality of the gingiva (the severity of the lesion) and the location (quantity) as related to the four (mesial, buccal, distal and lingual) areas which make up the total circumference of the marginal gingiva. At the time the Gingival Index was taken into use, the existing index systems - the P.M.A. Index (Massler and Schour, 1949), the Russell Index (1957) and the Periodontal Disease Index (Ramfjord, 1959) did not fulfil this requirement.

The D.H.C. Index of Suomi et al. (1970) is good in its approach to labial and lingual and gingival unit scoring. However, the severity index is too limited. Hazen (1974) feels that a "present-absent" approach would be as valid. Also the 'slight' inflammatory changes recorded by both Löe and Muhlemann are more sensitive than Suomi's requirement of a distinct colour change before inflammation is recorded. Meittner et al. (1979) support the gingival bleeding indices because bleeding is a more objective sign than colour change and their studies showed that a significantly greater number of subjects in their study manifested bleeding alone compared with
either visual inflammation alone or a combination of visual inflammation and bleeding. There is, however, a strong subjective component to a clinical examination for gingival bleeding due to the lack of standardisation of and control of insertion pressures. Therefore, the Löe approach which combines bleeding and colour change would appear to be most valid at this time (Hazen, 1974).

3.2.3 INDICES FOR ASSESSING PLAQUE

Plaque may be assessed by these methods:

1. Plaque area
2. Plaque thickness
3. Plaque weight.

These indices have been thoroughly reviewed by Mandel (1974).

3.2.3.1 Plaque Area Measurements

The following indices have been reviewed by Mandel (1974). His comments about each system are:

1. The Periodontal Disease Index (Ramfjord, 1956) - not well suited to clinical studies but is a reliable index for assessing periodontal disease.

2. The Oral Hygiene Index (Greene and Vermillion, 1960).
3. The Oral Hygiene Index - simplified (Greene and Vermillion, 1964). Both these indices of Greene and Vermillion use plaque disclosing agents which are unreliable due to inability of disclosing agent to distinguish between plaque and pellicle.
4. The Kupczak, Volpe and King scoring system (1969) - This system has limited application because it assesses plaque area in each one third of the tooth's surface - the area of greatest concern is the gingival third.

5. The Quigley and Hein system (1962) - This system is confined to the labial surfaces of the anterior teeth and gives greater attention to the gingival third.

Mandel (1974) claims that the limited evidence available indicates that techniques for measurement of total plaque area (as indicated by disclosing solutions) are subject to substantial error. In view of the paucity of data on lingual surfaces and posterior teeth, and the considerable time and effort involved, total area measurements would appear to have limited applicability to clinical studies.

3.2.3.2 Plaque Thickness Measurements

The only index that considers plaque thickness is the index of Silness and Löe (1964). In this system, a value of 2 is given to a moderately thick layer of plaque visible to the naked eye, and a value of 3 is given to a heavy deposit which fills out the gingival crevice.

The observations of Loesche and Greene (1972) indicate that unstained plaque scores correlate better with gingivitis and plaque weight than stained scores and hence the convenience of disclosing the plaque may be at the expense of accuracy when the index is to be related to gingivitis. The inherent error in assessing plaque with disclosing solutions is due to their inability to differentiate pellicle from plaque (Mandel, 1974).
Standardisation is not difficult using this index, provided the same examiner conducts the trial on the same group of patients.

3.2.3.3 Plaque Weight Measurements

The harvesting of plaque for weight assessment is a time consuming and precise procedure best suited to pilot studies. Removal of plaque directly from tooth surfaces and subsequent weighing is somewhat less precise, but is a much simpler procedure than collection of plaque on foil or mylar strip (Mandel, 1974).

Loesche and Greene (1972) found wet weight plaque measurements correlated more closely with gingivitis scores than did dry weight, also wet weight plaque collection is simpler than dry weight collection.

The advantage of a weight assessment over a visual assessment is that it is more accurate - selected teeth and selected surfaces can be used. However, the disadvantage is that it requires much more elaborate equipment and it does not lend itself to daily measurement (Mandel, 1974).

The correlation with both wet and dry weight with stained plaque scores was poor, a finding similar to that reported by Lobene (1974). It would appear that measurements assigned to stained areas frequently include a considerable amount of pellicle which would increase the numerical area score but have little effect on weight.
3.2.4 DISCUSSION

3.2.4.1 Gingival Indices

The critical evaluation of gingival inflammation is difficult at best. Suomi et al. (1970) reported a consistency amongst examiners of 80 percent agreement on gingival scores after a short period of training. The single examiner reproducibility is better than multiple examiners. This points out the problem in using indices which reflect a severity scale: examiner training is essential (Hazen, 1974).

Marked differences in the description of gingival inflammation also exist, e.g. Muhlemann et al. (1958) use bleeding upon gentle probing as a criteria for 'slight inflammation' and the Sulcus Bleeding Index has been devised, based on this premise. Løe et al. (1963) use early colour changes of the tissue and no bleeding on probing as their criteria for these early changes. Løe and co-workers have done a histological study on gingival tissue which correlated very well with the clinical index. Muhlemann and son (1971) were able to correlate the average gingival fluid flow rate of the marginal gingiva with the Sulcus Bleeding Index, but the correlation using individual units was poor. The Løe approach seems to be most critical and valid at this time.

3.2.4.2 Plaque Scores

One of the difficulties encountered in using the Silness-Løe index is the scoring of interdental areas (Mandel, 1974). The tendency is to score then from the facial aspect and assign a single score to the lingual area.
Two recent studies lend support to the validity and reliability of the plaque index. Lang et al. (1972) found a nearly linear correlation between the index as used on the facial surfaces of anterior teeth and on the total area of plaque as measured photographically with sodium fluorescein and a special light. When very small amounts of plaque were measured, the index was more consistent than the fluorescein technique. Loesche and Greene (1972) reported that unstained plaque scores correlated much higher than stained scores with gingivitis, dry and wet plaque weight.

3.2.5 ASSESSMENT OF LOSS OF PERIODONTIUM

In this particular study the ideal information would be to have a complete survey of the bottom of the gingival crevice related to the cemento-enamel junction for each cuspid tooth examined. However, such complete measurements cannot be obtained by any currently known technique and, as in most types of clinical studies, one has to settle for a sampling which is usually done on the basis of one sample measurement from each of the four side surfaces of each tooth (Ramfjord, 1974).

Furthermore, it has been found that combined distal and mesial measurements do not provide significant information that cannot be gained from mesial measurements alone, and the examining error is smaller for mesial than for distal measurements. Therefore, Jamison (1968) believes that adequate information regarding interproximal attachment levels can be obtained by mesial measurements of each tooth alone.
Hansson and Linder-Aronson (1972) found that there was increased pocket depth on the mesio-lingual aspect of the treated canine, whilst Wisth et al. (1976) found the distal pocket on the treated canine tooth was significantly deeper. Due to the specific nature of this study, four measurements will be taken of each canine tooth and the mesial and distal measurements will be assessed both labially and lingually, and the greater depth will be recorded.

3.2.5.1 Clinical Measurements

The most meaningful clinical data related to loss or gain of the periodontium are measurements of the distances from the cemento-enamel junction to the bottom of the probable crevice, and can be measured with probes on a millimetre scale with a high degree of reproducibility, providing the probes are well calibrated, equally thin, have equally shaped points, and are held in equivalent positions by the examiner (Ramfjord, 1967).

The thinner the probes are, the better is the reproducibility since such probes will penetrate to the bottom of the epithelium without a pain signal from the patient, while a thick probe will press against the connective tissue wall of the epithelial attachment and cause discomfort at an indefinitely defined stop. Probing should not be carried out after anaesthesia has been administered especially in cases of severe inflammation with loss of epithelial attachment and loss of collagen fibres at the bottom of the attachment.

Robinson and Vitek (1979) demonstrated a linear relationship between the gingival index (Löe and Silness, 1963) and the resistance of the gingival tissue to probe penetration.
With 30 pounds probing pressure the mean penetration at \( G_{1}=0 \) was 0.30 mm coronal to connective tissue attachment, whereas at \( G_{1}=3 \), the mean penetration at the same probing pressure was 1.25 mm apical to the connective tissue attachment.

If by loss or gain of periodontium one wishes to include loss or gain of free gingival tissues coronally to the bottom of the gingival crevice or periodontal pocket, data for such assessments can readily be obtained by probing and recording measurements from the free gingival margin to the cemento-enamel junction in some other fixed reference point on the tooth. Such measurements will provide much more accurate and reproducible information than gingival recession indices or cumbersome photogrammetry (Ramfjord, 1974).

3.2.5.2 Need for Special Recordings for Children

If probing of crevice depth and measurement of loss of periodontal support are related to the cemento-enamel junction, and if the cemento-enamel junction cannot be located by probe as is the case in some children, it has to be assumed there has been no attachment loss (Ramfjord, 1974).

Probing technique will be explained more fully in the method section of this thesis.

Ramfjord (1974) recommends that all measurements are rounded to the nearest millimetre, except that anything close to half a millimetre is always rounded to the lower whole number. Because there is a tendency with a thin probe to record a slightly greater depth than to the coronal level of the connective tissue attachment (Robinson and Vitek, 1979), depths of less than 1 mm below the cemento-enamel junction are not recorded unless the probing extends
definitely more than half a millimetre from the cemento-enamel junction (Ramfjord, 1974).

By assigning all the doubtful measurements to the lower score, the reproducibility is much greater than if a more accurate determination of half a millimetre were attempted.

3.2.5.3 Examiner variability

Reproducibility tests should be repeated prior to institution of a study until satisfactory results are achieved (Ramfjord, 1967; Glavind and Løe, 1967). Such tests should be repeated during and at the end of the study. The figures from such tests should be made available with the results of the investigation (Ramfjord et al., 1973); since with small variations in periodontal attachment levels with time, the accuracy of the scoring is crucial for a meaningful evaluation of the results.

Ramfjord (1967) recommends the following method for assessing scoring deviation: After the investigator has learned to use the index to the point that scoring becomes automatic and he can call off the figures without any hesitation, seven adult patients are selected at random and each patient is scored five times (not consecutively). The first and second, second and third, third and fourth, fourth and fifth and first and fifth scores from the individual teeth of each patient can be compared for the various measurements. No change is recorded as 0, increases of one unit as a +1, two units as a +2, or decreases of one unit as a -1 or two as a -2 in individual scores for examined teeth. As an example, it can be cited that in such a test, prior to a tooth brush study, a dental hygienist had an average deviation for periodontal scores and for crevice depth of 0.004.
Another test is to determine the pooled estimate of variance of the measurement errors for the five examinations of the seven patients. The variance from two tests, one at the beginning and another at the end of the study can be tested on the basis of an F study.

Besides the individual examiner's error, calibration has to be made for inter-examiner errors if more than one person does the scoring.

3.2.5.4 Conclusions

1. The method of Løe and Silness (1963) is most applicable to our purposes of measuring gingival inflammation as it combines bleeding and colour change, thereby reducing the subjectivity of the estimation and the method comes closest to the requirements of an index according to Davies (1968).

2. The Plaque Index of Silness & Løe (1964) is ideally suited to our study due to its simplicity, ease of application and because it was designed to match the Gingival Index of Løe and Silness (1963).

3. Attachment loss recordings (Glavind and Løe, 1967) to the nearest millimetre are highly reproducible, provided that a thin probe is used with uniform insertion pressures, and provided that all measurements are related to the cemento-enamel junction or other fixed landmark on the surface of the teeth.

4. At least one mesial, one buccal and one lingual measurement should be obtained from each of the experimental and control teeth.

5. Histometric and re-entry techniques are more accurate than clinical probing, but are not practical for clinical studies.
PART 4

CLINICAL STUDY
4. CLINICAL STUDY

INTRODUCTION

The aim of the study was to test the hypothesis that the surgical-orthodontically treated palatally impacted canine tooth has less bone support than the homologous tooth on the opposite side of the arch which has served as part of the anchorage system during the orthodontic treatment.

In selecting material for the study, the patients from the private practice were those patients who could be readily recalled and were willing to take part in the survey. In selecting material from the Dental Hospital, surgical records were consulted, however, these records did not go beyond April 1979 due to the re-organisation of the Department of Oral Surgery at about that time. Of 22 prospective patients, only 4 had completed their treatment and fulfilled the requirements for selection (see p.107). A minimum number of thirty patients is regarded as necessary to make the study statistically significant, therefore it was decided to classify the exercise as a pilot study.

Due to the relatively recent advent of the bonding technique at the United Dental Hospital, a further comparison could be made between bonded canines and ligated canines in order to show if there is any appreciable advantage of one technique over the other.
4.1 **SUBJECTS**

A total of ten subjects were chosen for the study. Six had been treated in private practice and four in the Orthodontic Department of the United Dental Hospital. Subjects were both males and females (6 males and 4 females) whose ages ranged from 15 years 1 month to 19 years 4 months. Nine of these patients had completed their treatment within the last six months one had completed his treatment 16 months previously.

4.2 **SELECTION**

All subjects chosen had to have completed their orthodontic treatment and they were selected on the basis that their pre-treatment condition included a unilateral palatally impacted canine tooth which had been surgically exposed and either ligated with soft stainless steel ligature wire or had been bonded with a mesh pad to which a gold chain had been welded and the tooth subsequently moved to its correct position in the arch. The small size of the sample limited the study so that groups could not be formed.

4.3 **EXPERIMENTAL DESIGN**

All subjects underwent an examination which involved the following:

1. Assessment of plaque - Silness and Löe (1964) - Both full mouth and separately for both treated and control teeth.
2. Assessment of gingivitis - Løe and Silness (1963) - Full mouth and separately for both treated and control teeth.

3. Assessment of pocket depth (Glavind and Løe, 1967) - on treated and control teeth.

4. Assessment of attachment loss (Glavind and Løe, 1967) - on treated and control teeth.


The selection of plaque and gingival indices was based on:

1. The ability of these indices to reflect accurately and reliably the status in gingival health.

2. The acceptance of using these indices in partial scoring of the mouth and using these scores as representative of the whole mouth (Lang, 1972; Greene and Vermillion, 1964; Shick and Ash, 1961; Jamison, 1968).

3. Their proximity to satisfying the requirements of an index as proposed by Davies (1968).

4.4 MEASUREMENTS AND ASSESSMENTS

4.4.1 EXAMINATION FOR PLAQUE

This was carried out using the plaque index of Silness and Løe (1964).
Criteria for Plaque Index

0 - no plaque in the gingival area.

1 - a film of plaque adhering to the free gingival margin and adjacent area of the tooth. The plaque may only be recognised by running a probe across the tooth surface.

2 - Moderate accumulation of soft deposits within the gingival pocket, on the gingival margin and/or adjacent tooth surface which can be seen by the naked eye.

3 - abundance of soft matter within the gingival pocket and/or on the gingival margin and adjacent tooth surface.

The area was lightly dried before recording the plaque index by means of a probe.

A partial mouth, after Silness and Löe (1964) was used. \(6 2 \frac{4}{4} \ 12 \frac{6}{6}\) were examined on mesial buccal and lingual surfaces, in addition to the treated and control teeth which were examined on all surfaces (mesial, distal, buccal and lingual).

4.4.2 ASSESSMENT OF GINGIVAL INFLAMMATION

This was recorded using the Gingival Index of Löe and Silness (1963). This index was chosen because the criteria are entirely confined to the qualitative changes in the gingival soft tissue.

Criteria for the Gingival Index System

0 - Normal gingiva

1 - Mild inflammation - slight changes in colour, slight oedema, no bleeding on probing.

2 - Moderate inflammation - redness, oedema and glazing. Bleeding on probing.
3 - Severe inflammation - marked redness and oedema. Ulceration.

Tendency to spontaneous bleeding.

Gingiva at six teeth representing the six segments of the jaws were examined to match the same six teeth as used in the Plaque Index.

Gingival scoring requires a light, mouth mirror and blunt periodontal probe as advocated by Løe (1967). The assessment of plaque always preceded that of gingiva. In the scoring procedure, missing teeth were substituted for by an adjacent tooth of the same type, as suggested by Greene and Vermillion (1960), and Quigley and Hein (1962).

For both plaque and gingival indices, a partial mouth scoring was used for assessing the whole mouth score. Ramfjord (1956) introduced the six tooth system of scoring for use with the P.D. Index. He scored $6\frac{1}{4} 1\frac{1}{4} 4\frac{1}{6}$.

Hazen (1974) recommends the partial mouth score for surveys but does not recommend its use in therapy studies. Mandel (1974) feels that for plaque, partial mouth scoring is adequate provided the anterior and posterior teeth are examined.

The author scored gingiva on patients in the Department of Periodontics with the Head of the Department as a form of preliminary training prior to commencement of the clinical study.

4.4.3 ASSESSMENT OF ATTACHMENT LOSS

Periodontal pocket depth and loss of attachment were measured on all surfaces (mesial, distal, buccal and lingual) of the treated
and control teeth.

'Pocket depth' refers to the distance from the gingival margin to the bottom of the clinical pocket. Mesial and distal pockets were measured from the buccal as well as from the lingual aspects as close as possible to the contact points. The larger reading was recorded. Buccal and lingual measurements were taken at the midline of the roots. Efforts were made to use a uniform insertion force. Pocket depth or loss of attachment of 1 mm or less was recorded as 1 mm, measurements exceeding 1 mm but less than 2 mm were recorded as 2 mm, etc. (Glavind and Löe, 1967).

'Loss of attachment' refers to the distance from the cemento-enamel junction to the bottom of the clinical pocket. Following the recognition of the cemento-enamel junction, the distance from the gingival margin to the cemento-enamel junction was measured. When the cemento-enamel junction was located apical to the gingival margin the loss of attachment would be the difference between the previously recorded pocket depth (A) and the distance (B) from the gingival margin to the cemento-enamel junction: \( A - B = \text{loss of attachment} \).

In cases where the marginal gingiva had been subject to recession and the cemento-enamel junction was exposed, the loss of attachment equalled the sum of the pocket depth and the distance from the gingival margin to the cemento-enamel junction: \( A + B = \text{loss of attachment} \).

Where the cemento-enamel junction could not be located by probing with a number 47 probe, it was presumed that the cemento-enamel junction was at the base of the sulcus and there was no attachment loss.
4.4.4 RADIOGRAPHIC EXAMINATION

4.4.4.1 Technique

An extended cone paralleling projection was used with a Rinn long cone aiming device. The film holder was modified by cutting off the sharp angles so that the holder could be positioned comfortably in the mouth (see fig. 20).

4.4.4.2 X-Ray Machine

All exposures of patients from the private practice were made with a Victor x-ray machine fitted with an extended cone. Kilo-voltage was fixed at 110 kv. Amperage was 5 m.amps. Exposures used were those recommended for an adult. Kodak DF45 films (small) were used.

Patients from the United Dental Hospital had x-ray exposures with a Siemens Heliodent 70 kv, 10 m.amp. machine with exposure time as recommended for an adult (two seconds for extended cone technique).

4.4.4.3 Processing

Processing was carried out by the Radiology Department at the United Dental Hospital. They use a standardised technique.

4.4.4.4 Measurement of Radiographs

The radiographs were placed into a 35 mm film holder and placed directly into a Kinderman AV100 slide projector and projected at 5x magnification onto a glass screen. (See Fig. 21)
FIG. 20  RINN LONG-CONE AIMING DEVICE

FIG. 21  KINDERMANN PROJECTOR
The bone height to cemento-enamel junction was then measured directly with a pair of Innox dental calipers with Vernier scale.

The bone height was assessed using the Kelly (1975) criteria. The bone height chosen was where the periodontal space still retained its normal width or where the lamina dura was no longer distinct. All measurements were made by the author. Bjorn et al. (1969b) state that the use of a single examiner gives the most reproducible results if performed within a limited period. Three separate measurements were recorded for each Bone Score to arrive at a mean score (Table 5).

4.5 STANDARDISATION PROCEDURES

4.5.1 STANDARDISATION OF PHYSICAL EQUIPMENT

To obtain consistent results, the equipment was standardised as far as practicable but because the patients in the study were derived from two sources, the physical equipment varied only as far as the x-ray machine was concerned.

4.5.1.1 Illumination

A constant light source was used to avoid the inconsistencies of natural light. A standard dental lamp affixed to the unit was used in both locations.

4.5.1.2 Drying of Teeth and Gingiva

For examination for plaque a light drying of the teeth was carried out to remove excess saliva. No cotton was used as this would interfere with soft deposits.
4.5.1.3 Mirrors

Plain front-surface unscratched 'Ash' mirrors were used throughout the study.

4.5.1.4 Periodontal Probes

A Vetter periodontal probe with Williams markings was used for plaque and pocket depth measurements. A standard Ash No. 47 probe was used to locate the cemento-enamel junction prior to measurement of the distance from gingival margin to cemento-enamel junction.

4.5.1.5 Examination Chart

All information including baseline information was recorded on a chart drawn up for the study by the author.

4.5.2 INFORMATION COLLECTED AT BASE LINE

In addition to information regarding plaque indices, gingival indices, and attachment loss, the following information was collected at the beginning of the examination:

(a) Name of subject
(b) Date of birth
(c) Sex
(d) Date of exposure and method of attachment.
(e) Date of cessation of active orthodontic treatment.
(f) Date of examination.
FIG. 22  No. 47 PROBE

'VETTER' PROBE

'INOX' CALIPERS

PLAIN 'ASH' MIRROR
4.5.3 SEQUENCE OF EXAMINATION

After the necessary base line information was collected from the subject, it was explained to each subject the nature of the study, after which the examination for all participants in the study was in the following sequence:

(a) Plaque score
   - Full mouth
   - Treated Tooth
   - Control Tooth

(b) Gingival score
    - Full mouth
    - Treated tooth
    - Control tooth

(c) Pocket depth
    - Treated tooth
    - Control tooth

(d) Attachment loss
    - Gingival margin to cemento-enamel junction distances
    - Treated tooth
    - Control tooth

(f) Radiographic examination
    - Treated tooth
    - Control tooth

4.6 REPRODUCIBILITY TRIALS

4.6.1 INTRODUCTION

All evaluation indices should be tested for reproducibility. The greater the number of subjective decisions and the less precise the criteria, the greater is the variability.
In this study, all assessments were made by one examiner - the author. Work by Davies et al. (1967) indicated that single examiner reproducibility is better than with multiple examiners. Smith et al. (1970) reported that even after a short period of training, examiners were able to reproduce their own scores 80 percent of the time.

The clinical trial study was commenced after an initial period of training by the Head of the Department of Periodontics.

Plaque Indices cannot be adequately tested for reproducibility on the same patient because once plaque is disturbed by probing, it will not reproduce within the short period of time (within say, half an hour) to be in keeping with the demands of a reproducibility trial.

Intra-examiner variability trials were carried out for Gingival Indices, Attachment Loss and Bone Scores.

4.6.2 GINGIVAL INDEX

Intra-examiner variability

The author practised scoring the gingival indices on dental students over the period of one week. The following week, a group of students were scored separately one hour apart to test the 'intra-examiner' reproducibility. The results showed a reproducibility on the part of the author of 80.6 percent (see Table 1).
4.6.3 ATTACHMENT LOSS

Intra-examiner variability

The author scored pocket depth measurements and cemento-enamel junction - gingival margin depths on 88 surfaces (6 measurements x 14 teeth) in one patient. A second set of measurements were taken one hour later to test the intra-examiner variability of attachment loss. Attachment loss is the depth of the gingival sulcus beyond the cemento-enamel junction. If the cemento-enamel junction is above the gingival margin, then the distance from the cemento-enamel junction to gingival margin is added to pocket depth to obtain the attachment loss. The results showed a reproducibility on the part of the author of 79.8 percent.

TABLE 1

GINGIVAL INDEX INTRA-EXAMINER REPRODUCIBILITY

<table>
<thead>
<tr>
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<th>First Reading</th>
<th></th>
<th></th>
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<th>Paired Scores</th>
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<td></td>
<td></td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
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<td></td>
<td>0</td>
<td>84</td>
<td>15</td>
<td>116</td>
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<td></td>
<td>1</td>
<td>11</td>
<td>28</td>
<td>Surfaces</td>
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<td></td>
<td>144</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
<td></td>
<td>% agreement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80.6</td>
</tr>
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</table>
TABLE 2
ATTACHMENT LOSS INTRA-EXAMINER REPRODUCIBILITY

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<td></td>
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<tr>
<td>% Agreement</td>
<td>79.8</td>
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</tr>
</tbody>
</table>

4.6.4 RADIOGRAPHIC INDICES

Reproducibility Trial

The author scored 40 radiographs until scoring the distance between the cemento-enamel junction and alveolar crest became automatic. A reproducibility trial was carried out on the 40 bone height scores by scoring these radiographs a second time one day later. (See Table 3)

Statistical Analysis - Reproducibility Trial

Standard deviation (N-1) = 0.167 (Using a statistical calculator)

Stand error of difference of means

\[
\frac{S.D.}{\sqrt{40}} = \frac{.167}{6.32} = 0.026
\]
Significance ratio (t) = \frac{\text{Difference between means}}{\text{Standard Error}}

= \frac{0.013}{0.026}

= 0.5

Not significant.

The difference between the first and second readings was not statistically significant.
4.7 STATISTICAL HANDLING

This study concerns a number of problems. The effect on bone and gingival tissues of the orthodontic and surgical treatment, plus the effect of the plaque retention on the orthodontic attachments during treatment should be considered in a study such as this.

Plaque and Gingival Indices are based on non-equidistant differences between consecutive scores and the analysis of plaque and Gingival Index scores presents a problem due to the ordinal character of the scoring system. It is not possible to calculate the results on the assumption that twice the score of 1 is equal to one score of 2, or one score 3 is three times a score 1. Hence, simple tables are presented, showing mean scores for each tooth and each patient and a mean score for the group. The scores on each surface of the treated and control teeth are then scored in the proportion of tooth surfaces in any situation which gave a plaque or gingival score of zero or one.

Bone height measurements are assessed by calculating standard deviation and standard errors and then 't' ratios are calculated to test the significance of the difference of the means of both mesial and distal bone heights, and also similar values are calculated to test the intra-tooth mesial to distal bone height differences.

Pocket depth and attachment loss measurements are assessed statistically on each surface - mesial, distal, buccal and lingual. Simple statistical calculations are presented and 't' values are given as the sample size is less than 30.

All mathematical calculations were done on a statistical calculator (Texas Instruments T.I. 35) by the author.
4.8 RESULTS

GENERAL ANALYSIS

4.8.1. Plaque Scores

The full mouth plaque scores all reflected good standards of oral hygiene. Of the ten patients examined, one patient scored greater than 1 (score 1.1). Mean plaque score for the sample (full mouth) was 0.64.

The treated and control tooth scores were similarly low - mean score treated teeth 0.45, control tooth 0.60 (see Table 4).

Table 4 shows the frequency of similar surfaces scoring 0 or 1. This adequately reflects the situation, showing that most treated and control teeth had low plaque scores. The distribution of scores of 2 did not indicate that treatment of the impacted canine had any detrimental effect on the proclivity of the tooth to retain plaque.

4.8.2 Gingival Scores

The treated teeth showed a slightly higher mean score than the control teeth (treated $\bar{x} = 0.55$, control $\bar{x} = 0.35$), the score on the control teeth being similar to the mean full mouth score ($\bar{x} = 0.34$).

When the separate surfaces were analysed, the treated teeth showed similar mean scores for each surface except for the mesial surface where the mean score was 1.2 for the treated sample and 0.5 for the control sample. Seventy percent of the mesial surfaces of treated teeth scored 0 or 1, whereas 100 percent of control teeth mesial surfaces scored 0 or 1. Thirty percent of mesial surfaces of treated teeth showed a score of 2, but none of the control teeth had scores of 2.
4.8.3 Pocket Depth and Attachment Loss

The mesial surfaces of treated and control teeth were the only surfaces to show a significant difference in pocket depths. Mean difference was 0.6 mm, S.D. ± 0.84 mm, p < .05. Difference between treated and control tooth attachment loss was significant, mesially with a mean loss of 0.4 mm (p < .05). Next was the buccal surface with a mean loss of 0.2 mm which was not significant (p > .05). Individual variation plays a part in these measurements and this was reflected in a 3 mm attachment loss on the distal surface of one control tooth.

4.8.4 Bone Loss

Average bone height differences mesially were 0.328 mm, S.D. ± 0.27 mm. This was significant at p < 0.01. Distally, the difference between treated and control teeth bone height was 0.895 mm, S.D. ± 0.82 mm which was also significant at p < 0.01. (Table 9).

Table 10 shows intra tooth distal to mesial differences. Control tooth differences in distal to mesial bone heights were a mean 0.137 mm S.D. ± 0.46 mm. Treated tooth distal to mesial measurements were a mean 0.804 mm, S.D. ± 0.68 mm (p < .01), which is significant. The difference in bone heights on the treated side distal - mesial was significant \( \bar{x} = 0.804 \text{ mm}, \text{ S.D.} \pm 0.68 \text{ mm (p < .01), whereas the control tooth distal to mesial bone height differences were a mean 0.137 mm, S.D.} \pm 0.46 \text{ mm, being insignificantly different.} \)
4.9 DISCUSSION OF RESULTS

The comparison of plaque and gingival scores of the treated and control teeth showed that the condition on the two sides was similar with relatively low scores for the majority of individuals, except for the mesial surfaces where the gingival scores were generally higher (mean score treated teeth 1.1, mean score control teeth 0.7). This agrees with Hansson et al. (1972). Wisth (1976) found that plaque and gingival scores were uniformly low - his results were not tabulated.

The gingival pocket depths were generally similar in both groups with pocket depth being slightly greater mesially and distally than the pocket depth of the control tooth. However, the gingival margin does not constitute a fixed line of reference and pocket depth does not necessarily correspond to the amount of periodontal destruction (Glavind and Löe, 1967; Ramfjord, 1959).

Hansson et al. (1972) found significant differences in the gingival pocket depths at the mesio-lingual areas. The mesial measurements used by the author are a mean measurement taken from the labial and lingual aspect, therefore the findings of this study tend to agree with those of Hansson et al.

The measurement of the attachment loss from the cemento-enamel junction to the base of the clinical pocket showed a loss of attachment in four cases, the mean loss for the group being 0.4 mm mesially. On the distal aspect, two persons showed attachment loss, the mean loss being 0.3 mm for treated teeth. Two cases showed a loss of attachment labially on the treated teeth, but none of the control teeth showed any loss.
Labial loss of support has been demonstrated by other workers: Sleichter (1971), Zachrisson and Alnaes (1974) state that the pressure side is particularly apt to show periodontal destruction even when it is not related to an extraction site.

The results showed negligible loss of attachment on the palatal aspect. This could be the result of surgical technique. Wisth et al. (1976) placed a surgical pack over the exposed canine and the canine was allowed to erupt into a palatal defect. The more conservative technique used in our group, where the palatal flap is replaced and the tooth is allowed to erupt, albeit with orthodontic assistance, through the palatal mucosa may explain the good results on the palatal aspect.

The attachment loss recordings at the distal aspect were negligible. However, these readings showed a large individual variation because one of the subject's control teeth had a loss of 3 mm distally which cancelled out the sum of 3 mm attachment loss present on two subjects' treated teeth.

Wisth et al. (1976) found significant attachment loss on his older group of patients (over 15 years) on the mesial surface. The findings of this author tend to agree with those of Wisth. However, our sample size was not large enough to indicate any firm conclusion in this regard.

Attachment loss recordings are subject to many problems, such as:

1. Inability to standardise insertion forces of the measuring probe.
2. Inability to accurately read the graduation mark.

3. Inability to predict the extent of penetration in healthy and slightly inflamed tissues.

The findings of this study agree with Zachrisson's (1973) study which showed a mean loss of attachment of 0.41 mm in the orthodontically treated group. However, in Zachrisson's (1979) study measurements were taken to the nearest 1 mm and his findings showed 'negligible' loss in the treated group.

At the proximal surfaces, the loss of attachment recorded clinically was not supported by the radiographic measurements of bone levels. Mean bone loss mesially was 0.34 mm, mean distal bone loss was 0.89 mm. A larger sample would be necessary to show any clear trends because in our sample of 10 cases, two cases demonstrated incomplete eruption of both treated and control teeth; and two cases showed an increased bone loss on the control teeth compared to treated teeth. One of the problems of measuring bone heights of canine teeth radiographically is the difficulty in obtaining a good x-ray of the area without overlap or distortion. The young palate has a shallow vault anteriorly and this makes the positioning of the x-ray film parallel to its contact points extremely difficult. Wisth et al. (1976) overcame this problem by using a mesio-centred and a disto-centred radiograph for each tooth. Hansson et al. (1972) used an index developed by Hollender et al. (1966) to measure bone loss. They found bone loss on the mesial side to be 'almost' significant.

Hansson et al. (1972) found significant bone loss mesially, whilst Wisth found almost 1 mm net bone loss mesially and distally on treated teeth.
Operator variables and individual variations of the patients' tendency to lose bone during orthodontic treatment play a large part in these measurements. Suffice to say, all studies found bone loss to be significant or almost significant mesially.

It was found in the study that measurement of bone height on radiographs posed several problems:

1. Indistinct cemento-enamel junction (Theilade, 1960). The cemento-enamel junction is not a point marking on the radiograph. It represents an area.

2. The alveolar crest is not clearly represented. In some cases a very thin crest is depicted as a blur on the x-ray, and an estimation of its position is made. This is a subjective measurement open to examiner error.

3. Overlap of distal surface of canine: This makes it very difficult to pinpoint the cemento-enamel junction and to see accurately, let alone define, alveolar crest. Mesio-centred and disto-centred radiographs would overcome this problem. However, it would increase the radiation dosage which is already not inconsiderable when using the long-cone paralleling technique which demands an exposure four times the usual time required for the short-cone 'bisecting-angle' technique.

4. Magnification of the radiographic image is useful in that measurements can be facilitated with greater accuracy. However, definition of the measured points which are already indistinct, is further blurred by the magnification of the image.
The author felt that the higher magnification is necessary when the measuring distances of 1 - 3 mm is made. In measuring such small distances, the degree of error must be reduced when magnification is increased, but this advantage is offset by the reduction of clarity.

Measurement of attachment loss distally does not correlate with the radiographic measurement of bone loss. This may be related to the difficulty in assessing the cemento-enamel junction on the distal aspect of the canine tooth. The distal enamel bulge coronal to the cemento-enamel junction masks the cemento-enamel junction; also access to the distal aspect of the canine tooth is not conducive to measurement in this area.

A number of problems were encountered in assessing plaque accumulation:

1. Subject manipulation: Many subjects prior to attending the dentist clean their teeth more thoroughly than is their usual habit, thus assessment does not reflect the usual state of their mouth. Gingival Index scores are not subject to such manipulation.

2. Plaque assessment:
   (a) Criteria. The method used by the author assesses plaque at the gingival margin, and the criteria suggested by Silness and Loe (1964) are not sufficiently well defined to meet the requirements of an Index system as proposed by Davies (1968).
   (b) Subgingival Plaque. This is not registered in our assessment and the subgingival plaque retained in the mesial and distal portions of the orthodontic
band may have a decided effect on attachment loss
and bone height, particularly on the control side
which is banded for a greater period of time than
the treated side.

3. Interproximal plaque: Assessment of plaque interproximally is
difficult to achieve with accuracy. Ainamo (1970) suggests assess-
ment from both buccal and lingual aspects and the greater score is
assigned to the mesial and distal surface.

The results of this study are in accordance with the findings
of Zachrisson and Zachrisson (1972 a, b) who found that interproximal
scores were greater than the facial areas.

The main problem in assessing gingival inflammation is in
deciding whether a given area of free gingiva is normal or slightly
inflamed. Some patients' gingivae is a deeper colour overall and
this fact was considered when assessing whether there was slight or
no inflammation. Other signs such as stippling and lack of swelling
are relied upon where the colour of gingiva is an unreliable guide
to assessment of inflammation.

A more complete study is indicated in this field, and it is
suggested that the base line data are taken prior to orthodontic
treatment and surgery, and that plaque and gingival scores are
assessed during the active phase of orthodontic treatment to assess
the affect of plaque on the control tooth and the treated tooth.
4.10 SUMMARY AND CONCLUSIONS

The purpose of this study was to assess the periodontal status of the orthodontically treated unilateral palatally impacted canine tooth.

A pilot study was carried out on ten patients selected from a Sydney Orthodontic practice and from the Orthodontic Department, University of Sydney.

All patients were selected on the basis that their pre-treatment malocclusion included a unilateral palatally impacted canine and treatment involving surgical exposure, some form of attachment, and subsequent orthodontic traction and alignment.

All subjects were assessed for the following:

4. Radiographic assessment to assess crestal bone loss utilising the extended cone paralleling technique. (Updegrave, 1968)

The results indicate:

1. Plaque scores on treated and control teeth were uniformly low. Mean full mouth score was 0.64, treated tooth mean score 0.45, control tooth mean score 0.65.
2. Gingival scores showed that the treated tooth score was slightly higher (mean score 0.55) than the control tooth (mean score 0.35), which was similar to the full mouth mean score (0.34).

Analysis of individual surface scores indicated that the mesial surface had a higher mean score (1.2) than the corresponding surface on the control tooth and this was substantiated by the fact that 30 percent of mesial surfaces of treated teeth had a score of 2, whilst 100 percent of mesial surfaces of control teeth had scores of 0 or 1.

3. Pocket depth difference was significant on the mesial surfaces only. The mean difference was 0.6 mm, S.D. ± 0.84 mm (p < .05).

Attachment loss was significant mesially with a mean loss of 0.4 mm (p < .05), and there was a mean labial loss of attachment of 0.2 mm which was not significant.

4. There was significant bone loss on the treated side both mesially and distally. Mesial bone loss was a mean 0.328 mm S.D. ± 0.27 mm significant at p < 0.01. Distal bone loss was a mean 0.895 mm S.D. ± 0.82 mm significant at p < 0.01.

The treated tooth distal to mesial bone height difference was a mean 0.804 mm ± 0.68 mm and this difference was significant when compared with the mesial to distal difference on the control tooth which was 0.137 mm ± 0.46 mm, which was not a significant difference.
The small number of cases in our study makes the subject of drawing positive conclusions very difficult. However, in view of the findings, one can make certain recommendations which may minimise periodontal pathology of the treated palatally impacted canine tooth.

1. A conservative surgical approach is warranted. The tooth should be exposed, bonded or ligated with minimal bone removal, and the palatal flap returned so that the tooth does not erupt into a 'defect'. Creation of a trough in the bone has not been shown to hasten eruption or expedite the movement of the tooth to its position in the arch.

2. The traction of the impacted tooth should be carried out in a vertical direction away from the roots of adjacent teeth, then in a labial direction. The appliances which do this most effectively are: (a) The palatal 'whip' spring;
   (b) The 'ballista' spring.

3. Care should be exercised in the final uprighting of the tooth. Gentle forces should be used so that crestal bone height mesially and distally is preserved, and care should be exercised when the roots of canines are inclined labially, thereby respecting the original deficiency of canine eminence. The object of this manoeuvre is to avoid the creation of a root fenestration or dehiscence.

4. Careful attention should be paid to oral hygiene during treatment. The lingual position of the tooth upon eruption, makes the tooth and traction appliance very difficult to clean. Continual re-enforcement of oral hygiene procedures is necessary to maintain a high standard of oral hygiene throughout treatment and this effort should enhance the patients' awareness of oral hygiene after cessation of orthodontic treatment.
The present study could be extended to:

1. Collection of base line information such as plaque and gingival scores and crestal bone heights of control teeth before surgical exposure is implemented, so that a meaningful comparison of these findings can be made after treatment.

2. The periodontal status of the treated tooth could be related to an index of severity of impaction such as the 'Rayne's Index'.

3. The two main techniques of attachment - bonding and ligation - could be assessed. The same oral surgeon and orthodontist performing the treatments would minimise operator variables.

4. Any future study must have sufficient numbers of subjects (up to 30) to be statistically meaningful.
# TABLE 3

**REPRODUCIBILITY TRIAL**

Bone Scores (mm). Cemento-Enamel Junction to Alveolar Crest Distance.  

N = 40

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Mean 3.645  
3.658  

.013 (ignoring the sign)  

Difference of means = 0.013
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PLAQUE SCORES

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<td>0.17</td>
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<td>0.33</td>
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FREQUENCY OF DISTRIBUTION OF SCORES ON SIMILAR SURFACES

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RATIO OF SIMILAR SURFACES SCORING 0 or 1

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### TABLE 5

**GINGIVAL SCORES**

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</table>

\[ \bar{x} \quad 1.2 \quad 0.5 \quad 0.2 \quad 0.3 \quad 0.55 \quad 0.5 \quad 0.1 \quad 0.3 \quad 0.35 \quad 0.34 \]

#### FREQUENCY OF DISTRIBUTION OF SCORES ON SIMILAR SURFACES

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<td>Treated Control</td>
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#### RATIO OF SIMILAR SURFACES SCORING 0 OR 1

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<td>1 2 2 2 2 2 1 1</td>
<td>1 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>M.F.</td>
<td>3 2 1 1 3 2 1 2</td>
<td>2 1 1 1 3 2 1 2</td>
<td>1 1 0 0 0 0 0 0</td>
</tr>
<tr>
<td>D.F.</td>
<td>3 3 1 2 2 3 1 2</td>
<td>3 3 0 2 2 3 1 2</td>
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</tr>
<tr>
<td>K.H.</td>
<td>2 2 1 2 2 2 1 1</td>
<td>1 2 0 2 2 2 1 1</td>
<td>1 0 1 0 0 0 0 0</td>
</tr>
<tr>
<td>S.C.</td>
<td>3 2 1 1 1 2 2 2</td>
<td>3 2 1 1 1 2 2 2</td>
<td>0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>J.L.</td>
<td>3 2 1 1 1 2 2 1</td>
<td>2 2 1 1 1 2 2 1</td>
<td>1 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>P.L.</td>
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<td>2 2 1 2 2 2 1 2</td>
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</tr>
<tr>
<td>G.N.</td>
<td>3 3 2 2 3 2 2 2</td>
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</tr>
<tr>
<td>N.F.</td>
<td>2 2 1 1 2 2 1 1</td>
<td>2 2 1 1 2 2 1 1</td>
<td>0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>A.B.</td>
<td>3 2 2 1 2 3 1 1</td>
<td>3 0 2 1 2 0 1 1</td>
<td>0 2 0 0 0 3 0 0</td>
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</table>
## TABLE 7

**BONE SCORES OF TREATED AND CONTROL TEETH (mm).**

**EACH MEASUREMENT REPEATED THREE TIMES**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Treated Teeth</th>
<th>Control Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mesial</td>
<td>Mean</td>
</tr>
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</tr>
<tr>
<td></td>
<td>1.1</td>
<td>1.8</td>
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</tr>
<tr>
<td></td>
<td>3.4</td>
<td>1.13</td>
</tr>
<tr>
<td>M.F.</td>
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<td>3.0</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>6.7</td>
<td>2.23</td>
</tr>
<tr>
<td>D.F.</td>
<td>1.7</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
<td>1.87</td>
</tr>
<tr>
<td>K.H.</td>
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<td>1.8</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>1.5</td>
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</tr>
<tr>
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<td>1.6</td>
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<td>1.6</td>
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<td>0.9</td>
</tr>
<tr>
<td></td>
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<td>1.3</td>
</tr>
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</tr>
<tr>
<td></td>
<td>0</td>
<td>3.5</td>
</tr>
<tr>
<td>P.L.</td>
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<td>1.6</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
<td>1.73</td>
</tr>
<tr>
<td>G.N.</td>
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<td>2.4</td>
</tr>
<tr>
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<td>1.9</td>
<td>2.6</td>
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</tr>
<tr>
<td></td>
<td>5.9</td>
<td>1.97</td>
</tr>
<tr>
<td>N.F.</td>
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<td>3.0</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>2.7</td>
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<td>2.9</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>1.67</td>
</tr>
<tr>
<td>A.B.</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>3.7</td>
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<td>3.8</td>
</tr>
<tr>
<td></td>
<td>6.4</td>
<td>2.13</td>
</tr>
</tbody>
</table>
TABLE 8

CEMENTO-ENAMEL JUNCTION TO ALVOLAR CREST MEASUREMENTS (mm) (CEJ-AC)

<table>
<thead>
<tr>
<th></th>
<th>Treated</th>
<th>Control</th>
<th>Treated to Control</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mesial</td>
<td>Distal</td>
<td>Mesial</td>
<td>Distal</td>
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<td>E.S.</td>
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<td>1.6</td>
<td>0.1</td>
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<tr>
<td>M.F.</td>
<td>2.23</td>
<td>3.43</td>
<td>1.87</td>
<td>1.40</td>
</tr>
<tr>
<td>D.F.</td>
<td>1.87</td>
<td>3.77</td>
<td>1.40</td>
<td>1.50</td>
</tr>
<tr>
<td>K.H.</td>
<td>1.47</td>
<td>1.60</td>
<td>0.77</td>
<td>1.17</td>
</tr>
<tr>
<td>S.G.</td>
<td>1.47</td>
<td>1.60</td>
<td>1.40</td>
<td>1.60</td>
</tr>
<tr>
<td>J.L.</td>
<td>0</td>
<td>1.17</td>
<td>0.78</td>
<td>0.70</td>
</tr>
<tr>
<td>P.L.</td>
<td>1.73</td>
<td>1.57</td>
<td>1.30</td>
<td>1.23</td>
</tr>
<tr>
<td>G.N.</td>
<td>1.97</td>
<td>2.47</td>
<td>1.67</td>
<td>2.17</td>
</tr>
<tr>
<td>N.F.</td>
<td>1.67</td>
<td>2.87</td>
<td>1.10</td>
<td>1.73</td>
</tr>
<tr>
<td>A.B.</td>
<td>2.13</td>
<td>3.63</td>
<td>2.0</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>15.67</td>
<td>23.71</td>
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<td>14.76</td>
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<tr>
<td>$\bar{x}$</td>
<td>1.567</td>
<td>2.371</td>
<td>1.239</td>
<td>1.476</td>
</tr>
<tr>
<td>S.D.</td>
<td>0.64</td>
<td>0.99</td>
<td>0.57</td>
<td>0.71</td>
</tr>
<tr>
<td>S.E.</td>
<td>.2</td>
<td>.31</td>
<td>.18</td>
<td>.22</td>
</tr>
</tbody>
</table>

$t$ $p$

2.52 $<.05$

3.285 $<.01$

* Where the control tooth measurement is greater than the treated
tooth measurement due to incomplete eruption, a zero score is given.
| Table 9 |
| Comparison of Periodontal Condition of Treated and Control Teeth |

<table>
<thead>
<tr>
<th></th>
<th>Treated</th>
<th></th>
<th></th>
<th>Control</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>( \bar{x} )</td>
<td>SD ( \bar{x} )</td>
<td>SE ( \bar{x} )</td>
<td>( \bar{x} )</td>
<td>SD ( \bar{x} )</td>
<td>SE ( \bar{x} )</td>
<td>SD of Diff.</td>
<td>SE of Diff.</td>
</tr>
<tr>
<td><strong>Pocket Depth</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Mesial</td>
<td>2.6</td>
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<td>2.0</td>
<td>0.67</td>
<td>.212</td>
<td>0.84</td>
<td>.266</td>
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<tr>
<td>Distal</td>
<td>2.2</td>
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<td>.133</td>
<td>2.2</td>
<td>0.42</td>
<td>.133</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Buccal</td>
<td>1.3</td>
<td>0.48</td>
<td>.152</td>
<td>1.3</td>
<td>0.48</td>
<td>.152</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Lingual</td>
<td>1.5</td>
<td>0.53</td>
<td>.168</td>
<td>1.5</td>
<td>0.53</td>
<td>.168</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>Loss of Attachment</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesial</td>
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<td>0.52</td>
<td>.165</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
<td>0.52</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Buccal</td>
<td>0.2</td>
<td>0.42</td>
<td>.133</td>
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<td>0</td>
<td>0</td>
<td>0.2</td>
<td>0.42</td>
</tr>
<tr>
<td>Lingual</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td><strong>Bone Height (AC-CEJ)</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mesial</td>
<td>1.567</td>
<td>0.64</td>
<td>.202</td>
<td>1.239</td>
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<td>.180</td>
<td>0.328</td>
<td>0.27</td>
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<tr>
<td>Distal</td>
<td>2.371</td>
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<td>.313</td>
<td>1.476</td>
<td>0.71</td>
<td>.225</td>
<td>0.895</td>
<td>0.82</td>
</tr>
<tr>
<td>Distal-Mesial</td>
<td>0.804</td>
<td>0.68</td>
<td>.215</td>
<td>0.137</td>
<td>0.46</td>
<td>.146</td>
<td>0.667</td>
<td>0.70</td>
</tr>
</tbody>
</table>
### TABLE 10

**DISTAL TO MESIAL BONE HEIGHT DIFFERENCE (INTRA TOOTH)**

<table>
<thead>
<tr>
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<th>Treated (D-M)</th>
<th>Control (D-M)</th>
<th>Difference</th>
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</thead>
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<td>E.S.</td>
<td>0.47</td>
<td>0.26</td>
<td>0.21</td>
</tr>
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<td>M.F.</td>
<td>1.20</td>
<td>-0.47</td>
<td>1.67</td>
</tr>
<tr>
<td>D.F.</td>
<td>1.90</td>
<td>0.10</td>
<td>1.80</td>
</tr>
<tr>
<td>K.H.</td>
<td>0.13</td>
<td>-0.60</td>
<td>0.73</td>
</tr>
<tr>
<td>S.C.</td>
<td>0.13</td>
<td>0.20</td>
<td>-0.07</td>
</tr>
<tr>
<td>J.L.</td>
<td>1.17</td>
<td>-0.08</td>
<td>1.25</td>
</tr>
<tr>
<td>P.L.</td>
<td>-0.16</td>
<td>-0.07</td>
<td>-0.09</td>
</tr>
<tr>
<td>G.N.</td>
<td>0.50</td>
<td>0.50</td>
<td>0</td>
</tr>
<tr>
<td>N.F.</td>
<td>1.20</td>
<td>0.63</td>
<td>0.57</td>
</tr>
<tr>
<td>A.B.</td>
<td>1.50</td>
<td>0.90</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>8.04</td>
<td>1.37</td>
<td>6.67</td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>.804</td>
<td>.137</td>
<td>.667</td>
</tr>
<tr>
<td>S.D.</td>
<td>.68</td>
<td>.46</td>
<td>.70</td>
</tr>
<tr>
<td>S.E.</td>
<td>.215</td>
<td>.146</td>
<td>.22</td>
</tr>
<tr>
<td>t</td>
<td>3.74</td>
<td>.938</td>
<td>3.03</td>
</tr>
<tr>
<td>p</td>
<td>$&lt;.01$</td>
<td>$&gt;.2$</td>
<td>$.01$</td>
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(Significant) (NS) (Significant)
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