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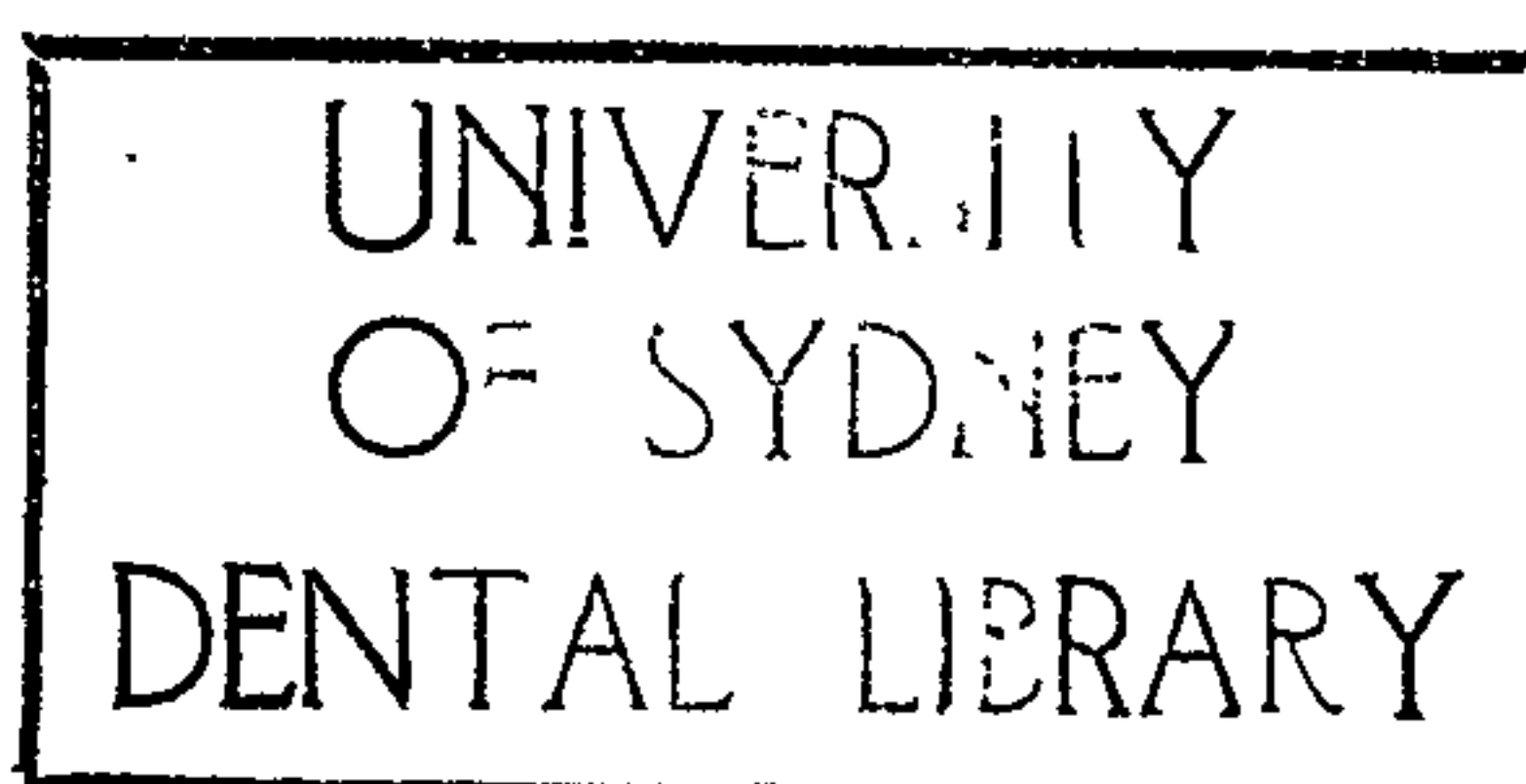
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BIOMETRICS WITH THE PALATALLY DISPLACED

MAXILLARY PERMANENT CANINE

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the degree of Master of Dental Science.



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## SECTION 1

### INTRODUCTION

Palatal displacement of the maxillary permanent canine is not a recent phenomenon, but one that is becoming increasingly observed. Weinberger (1915) found amongst the works of Gaius Plinius Secundus (otherwise known as Pliny, the Elder, A.D. 23-79) the comment that "there once lived a man who had a tooth in his palate". Whether this tooth was in fact a canine is not known, yet this remains perhaps the earliest record of palatal tooth displacement.

It wasn't until 1847 that John Tomes first presented several specimens (skulls) showing palatally displaced and unerupted canines. He believed the cause of this irregularity was defective growth resulting in insufficient space in the jaw (Weinberger, 1916).

N. W. Kingsley in 1858 described a method of treating "the eye-tooth closing within the lower jaw", a manifestation he thought not uncommon (Weinberger, 1917). In fact, many illustrations appeared in the "Dental Cosmos" published in the latter half of last century that described appliances used for erupted palatally displaced canines attesting to the relative frequency of this anomaly (Weinberger, 1915-1919).

Palatally displaced canines have been blamed for many abnormalities, from headaches to mental illnesses (Section 3.4.1). They are probably the major cause in the belief of the laity in the third dentition of Man (Erikson, 1938).

A general feeling among contemporary orthodontists is that the incidence of palatally displaced canines is increasing (Mollenhauer, 1985). Whether this is a true

increase or merely a reflection of increased community awareness of esthetics that has resulted in more patients seeking treatment for palatally displaced canines is unknown.

Equally unknown is the cause of this anomaly. Many factors have been purported but none has been demonstrated definitively (Section 3.5). Emphasis has recently been taken away from the time-honoured view that crowding of the dental arch is the major cause of palatal canine displacement (Section 3.5.1.8). It has been subrogated with the view that **excess** space in the maxilla, either from excessive growth of the maxillary basal bone or from aberrant lateral incisor morphology, allows the canine to drift palatally to the lateral incisor root and lose its guidance into the arch.

Recent studies (Becker and co-workers, 1981-1986) have concentrated on the morphology of the lateral incisor crown and root. However, this is just one aspect in a complex melange of local factors that contribute towards palatal displacement of the canine. This thesis is an attempt to explore the effects of local factors on the dentition and palate associated with palatal displacement of the maxillary permanent canine and to determine biometrically which factors might be most involved. With this knowledge at hand, secondary prevention (interceptive therapy) via early diagnosis might be facilitated.

## SECTION 2

### THE MAXILLARY PERMANENT CANINE

#### 2.1 SIGNIFICANCE

The value of the maxillary permanent canine to the face and dentition has long been perceived. Talbot (1890) recognised the importance of the upper cuspid "in determining the outline of the wing of the nose and upper lip and giving character to the face". Its position at the junction of the anterior and posterior teeth has caused it to be described as the "cornerstone" of the maxillary arch (Kay, 1977).

Rarely is this tooth congenitally absent. Hallett and Weyman (1954) believed the incidence of absence to be less than 0.13%, considering this to be Nature's testimony to the canine's importance. More recently, Brin, Becker, and Shalhav (1986) determined the incidence of absence of the maxillary canine to be 0.08%.

Whilst the canine is relatively resistant to dental caries and periodontal disease (Jackson, 1965), its major value lies in its long root, excellent bony support, and characteristic crown shape. These endowments allow it to exert a stabilising influence on occlusal forces by assuming the major occlusal load during mastication. The highly developed proprioceptive abilities of the canine helps protect the remaining teeth and add to the longevity of the dentition (Dewel, 1949b; D'Amico, 1961; Klineberg, 1985).

Clinical absence of the canine, either

congenitally or by impaction or extraction, can reduce the esthetic value of the arch and face and can diminish social attractiveness (Shaw, Rees, Dawe, and Charles, 1985). Deprived of a major load bearing structure, the masticatory system will show reduced efficiency, and the poor anatomical contacts between lateral incisors and first premolars can become a site for food impaction and a nidus for infection (Rayne, 1969).

Lane (1962) epitomised the thoughts of the orthodontist regarding the significance and value of the maxillary canine when he wrote:- "Possibly 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".

## 2.2 NORMAL APPEARANCE

The maxillary canine (also referred to as "cuspid", or by lay people as "eye-tooth") is the longest of all teeth, and is the largest and most robust of the anterior teeth. Its length varies considerably. An anthropological study in New Zealand by Taylor (1969) gave a range of 18 mm to 35 mm in length. Black (1902) in the U.S.A. found canine length to range from 20 mm to 32 mm (average 26.5 mm), and Campbell (1925), measuring Australian Aboriginal teeth, found a range of 22.5 mm to 32.5 mm (average 27.5 mm).

The crown is often described as diamond-shaped, probably due to the acumination of its cusp, but may be better described as pentagonal (Taylor, 1969). The mesial incisal edge is usually shorter and more horizontal than the distal incisal edge

and acumination may vary from a true point through all degrees of bluntness to almost the cuspless edge of an incisor. Incisal edges tend to be convex, but can also be straight or even concave.

The labial surface is convex in both axes and has a broad longitudinal ridge from cervix to cusp tip. This ridge has furrows on each side, the distal usually more distinct, and gives the crown a trilobular appearance.

The lingual surface shows a strong cingulum and may actually present a small lingual cusp separated by a groove or fissure from the main cusp. Marginal ridges extend each side of the cingulum to the incisal edges, and a longitudinal ridge passes centrally to the incisal tip. Between this ridge and the marginal ridge on each side can be found a shallow groove or fossa. It is the central ridge on the lingual surface that makes the cuspid so robust.

The proximal surfaces of the crown are more extensive labiolingually than those of the incisors due to the robustness of the cuspid crown. The mesial surface is usually larger and more vertical than the distal surface and both are convex. The enamel margin is concave on both sides, the mesial being somewhat more V-shaped.

The root is very long and strong. It is straight and evenly tapered, and compressed mesiodistally where there may be furrows present. The apical third of the root can occasionally be bent in any direction, usually distally. This is because the roots of the anterior teeth must conform to the local bony configuration (i.e. the relative size and position of the alveolar process, nasal fossa and maxillary sinus). Related to the root of the

cuspid is a bony pillar of the face bordered inferiorly by the maxilla, mesially by the nasal fossa, and laterally by the maxillary sinus. This pillar allows the cuspid root to be longer than the roots of adjacent teeth. Depending on whether the cuspid is below or to one side of this pillar, the apical part of the root may be straight or bent to conform to the sinus or fossa. Labial deviation of the apex may conform to the anterior wall of the sinus and be subjected to modification of alveolar bone in relation to the anterior floor of the fossa.

Very rarely the cuspid may have two roots - one labial and one lingual (Gabriel, 1965; Taylor, 1969).

In normal **occlusion** the maxillary canine is positioned posterolabially to the mandibular canine and inclined mesially such that the cusp tip rides on the distoincisor inclines of the mandibular canine on the laterotrusive side during lateral mandibular excursions. This provides disclusion of the posterior dentition on both the laterotrusive and mediotrusive sides. If there is insufficient mesial inclination of the maxillary canine, the cusp tip will pass through the embrasure between the mandibular canine and first premolar, no posterior disclusion will occur and interferences will result on both sides of the mouth (Roth, 1985). Excessive mesial inclination of the maxillary canine may not affect its disclusion capabilities as much as it allows mesial movement of maxillary buccal teeth (simply maintaining physiological contact) and a loss of Angle's Class I buccal occlusion (Dewel, 1949a).

## 2.3 DEVELOPMENT AND ERUPTION

Although the term "eruption" correctly refers to the breaking through of the hard and soft tissues of the jaw by the tooth and its subsequent movement to its functional position in the occlusal plane, common usage has included the occlusal movement of the tooth through bone from its developmental position within the jaw as part of "eruption".

Ten Cate (1976) describes the pattern of tooth movement as having three phases:- (a) a **pre-eruptive phase** where the tooth germs of the deciduous and permanent dentitions move relative to each other, adjusting position due to growth of the infant jaws and as preparation for eruption; (b) an **eruptive phase** where the tooth moves from its position within the bone of the jaw to a functional position in occlusion, generally along the line of its axial direction but modified by growth; and (c) a **post-eruptive phase** where tooth movement maintains tooth position during continued jaw growth, and compensates for occlusal and proximal attrition (mainly axial and mesial migratory movements).

Development and eruption overlap to a certain degree but are considered here separately.

### 2.3.1 Development

From a developmental point of view, no tooth is more interesting than the maxillary permanent canine. With the longest period of development, it has the most devious course to travel from its origin to full occlusion. Unlike other teeth, it has no constant site of

development but rather, occupies several different developmental positions in succession during its peregrination (Dewel, 1949b).

Embryologically, from about the fifth month in utero, the dental lamina (the epithelial band composed of the developing tooth germs), having initiated the entire deciduous dentition, proceeds to form an outgrowth on its free end which lies lingual to the enamel organs of each deciduous tooth. This outgrowth, the successional lamina, is the site of initiation of the permanent successional dentition which includes the maxillary canine (Bhussry, 1976).

Initially, the permanent tooth germs in the maxilla lie lingual to their corresponding deciduous tooth germs without deviating mesially or distally. Furthermore, they are located not on the same level in relation to the oral epithelium, but slightly more superficially. With development, the successional lamina separates and disintegrates allowing the permanent tooth germs to move relative to each other. In particular, the anterior tooth germs move occlusally and mesially to their predecessors, although not so markedly in the canine's case.

The maxillary canine primordium is separated widely from the lateral incisor and first premolar, and extends labially and deeply in relation to the deep position of the deciduous canine.

Individual variation of growth direction occurs in the anteriors such that the central incisor is directed labially, the lateral incisor which lies more superficially is directed palatally, and the canine extends labially. Like the deciduous tooth germs, the permanent tooth germs develop in an uneven arcade and the dental and successional laminae (or remnants thereof) show a marked bowing in the canine region reflecting the slower, steadier growth of these teeth (Ooe, 1981).

At birth, the central incisor is quite large and has reached bell stage. The lateral incisor varies from bud to cap stage, and the canine is quite bulky in the cap stage and approximately 1.0 mm in diameter. The first premolar is beyond bud stage but shows no histodifferentiation (Kronfeld, 1935; Ooe, 1981).

Eruptive movements of the deciduous teeth and alveolar bone formation relocate the permanent tooth germs lingually and apically. The central incisor lies near the floor of the nasal cavity while the lateral incisor remains undifferentiated. The canine lies in the angle between the piriform aperture and the maxillary sinus and at a higher level than the others, immediately below the floor of the orbit (Miller, 1963; Salzmann, 1974).

Histologically, Logan and Kronfeld (1933) and Kronfeld (1935) found that by six months of age the tip of the canine is

calcified (calcification begins about four months postnatally), although there is somewhat less enamel and dentine present (1.0-1.5 mm in height) than has the central incisor. The lateral incisor is still in bud or cap stage.

At **nine months**, evidence is already present of the slowing rate of development of the canine. The calcified portion of the central incisor measures approximately 4.0 mm, that of the canine approximately 3.0 mm.

The lateral incisor begins to calcify at **one year**. The canine at this stage shows an enamel cap of 3.5 mm high and 2.0 mm thick, but of immature type enamel. This shows itself radiographically for the first time with the canine appearing to be forming between the roots of the deciduous first molar when viewed on the true lateral cephalograph (Broadbent, 1941). The developing first premolar at this age is migrating from its previous position occlusal to the lingual cusps of the deciduous first molar to a position in the furcation of the deciduous first molar via the mesial aspect of the lingual root (coincident with clinical eruption of the deciduous first molar).

It's of interest to note that Broadbent (1941) describes the common site of origin of the canine and first premolar (between the roots of the deciduous first molar) as "significant", and that this description is echoed by Dewel (1949b), Hunter, (1981) and others. On a

two-dimensional radiograph the canine appears above the erupting deciduous first molar (whose roots are still forming) and then later above the first premolar resting in the furcation. Logan and Kronfeld (1933) also note the canine present "in the same field" as the first premolar and deciduous first molar in histological sections. However, prepared skull specimens allow a three-dimensional view (van der Linden and Duterloo, 1976) and show at the same age the calcified cusp tip of the canine lying lingual to the furcation of the deciduous first molar and at the same level or even more lingual than the developing lingual root. As the first premolar develops, the canine is still lying lingually but slightly more mesially, with the bulbous crown form extending labially from the cusp tip giving the appearance of a lingually directed crown.

At **eighteen months**, the canine has an enamel cap of 4.5 mm, the central incisor 7.5 mm, and the rapidly developing lateral incisor 3.5 mm. The first premolar is beginning to calcify. By **two years**, the lateral incisor and canine are in the same stage of development, and by **three years**, the lateral incisor is ahead. The central and lateral incisor crowns are fully formed by five years, the canine crown by six years. The first premolar is also fully formed and enamel matured by six years (Kronfeld, 1935). Lewis and Garn (1960) and Nolla (1960) noted sex differences in calcification, females showing earlier dental maturation

than males. However, no significant differences were found between left and right side tooth development.

Three important facts came from this data:-

- (1) the central incisor and canine develop almost simultaneously yet erupt five or six years apart;
- (2) the lateral incisor begins to develop six to nine months after the canine yet finishes one year earlier; and
- (3) the first premolar begins its development one year after the canine and finishes at the same time.

Perhaps the reason for the slow development of the canine crown stems from its being the biggest and bulkiest of the anterior crowns and would require more time to form. Also of consideration is the amount of space present in the anterior maxilla early in life, which, according to Logan and Kronfeld (1933), may be the reason development of the lateral incisor is held back until sufficient growth has occurred to accommodate it.

As the deciduous teeth erupt, the developing permanent incisors and canines migrate forward so that by **three years** the canine is situated above and lingual to the apex of the deciduous canine. Growth of the face and jaws carries the deciduous

dentition downwards and forwards, thereby allowing more space for the developing permanent teeth. The canine, however, remains high in the maxilla and doesn't seem to move from this position until the crown is completed (Broadbent, 1941; Moss, 1971; Hunter, 1981).

Two anatomical traits are present at this age, for neither of which is the reason or function really known. One is the thick bony septum running inferolaterally from the corner of the piriform aperture. This septum separates the canine from the central incisor which is quite close. The lateral incisor is lying palatally to the central incisor and under this septum (van der Linden and Duterloo, 1976). Gabriel (1965) has suggested this structure may be involved in transmission of stresses and reduction of forces during mastication (i.e. bone adapts in structure so as to suffer minimum strain).

The other structure present is the gubernacular cord lying in the gubernacular canal which presents as a foramen lingual to the deciduous tooth and runs vertically down to the successional tooth crypt (Fastlicht, 1954; Salzmann, 1974). The cord consists of remnants of dental lamina and connective tissue and is thought by Ten Cate (1976) to perhaps function in guiding the eruption of the permanent teeth.

### 2.3.2 Eruption

Following completion of crown development, the canine undergoes root formation from

about seven years of age (Nolla, 1960; Hunter, 1981). The central incisor has generally erupted at this age and the lateral incisor is usually erupting thereby creating more space in the maxilla for the canine. Root formation moves the canine occlusally until contact is made against the developing root of the lateral incisor.

The canine is still positioned lingual to its deciduous precursor but the cusp tip is now one-third the root length from the apex of the deciduous canine (van der Linden and Duterloo, 1976). Its position here is governed by its mesial contact against the distal aspect of the lateral incisor root, and its distal contact with the crown of the first premolar. This latter contact conforms with the mesial surface concavity of the first premolar crown, a morphological feature which may act not only to help guide the eruption of the canine but also to guide the distal repositioning of the first premolar when the canine does erupt.

As the canine moves down the distal aspect of the lateral incisor root, the "ugly duckling" stage of tooth development described by Broadbent (1941) may take place. The lateral incisor crowns are seen to flare laterally, the apices converging. It is not until the canines are fully in the arch that the apices of the lateral incisors gain enough space to upright correctly, due mainly to an increase in width of the subnasal area as measured by an increased width of the piriform aperture (Newcomb, 1959).

Just as the deciduous teeth are crowded prior to jaw growth to accommodate them after eruption, so are the permanent teeth crowded in similar patterns to the deciduous teeth (van der Linden, McNamara Jr., and Burdi, 1982; Ooe, 1981). It was Mead (1930) who told us to "remember that the jaw accommodates itself to and is changed in shape by the teeth, and not vice versa".

Clinically, the canine can be palpated high on the alveolar process above the deciduous canine from about eight years of age. This bulge becomes more prominent with movement of the canine buccally and occlusally along the lateral incisor root as well as because of widening of the subnasal region (Williams, 1981).

The close relation between the canine and the root of the lateral incisor indicates the latter tooth plays a significant role in guiding normal eruption of the canine. This is exemplified when the lateral incisor is missing (absent) and the canine erupts mesially into the lateral incisor space (Moss, 1971; Becker, Smith, and Behar, 1981).

Moss (1971) believes eruption into the oral cavity occurs when three-quarters of the canine root is completed. Altonen and Myllarniemi (1976), however, consider alveolar eruption is occurring at this stage of root development and that clinical eruption occurs when the root has reached its full length but the apex is incomplete (open).

Eruption occurs between nine and a half and twelve and a half years in girls and between ten and a half and thirteen years in boys. Root formation is completed within two years of eruption and any physiological diastema still present in the arch prior to canine eruption generally closes (Broadbent, 1941; Miller, 1963; Moss, 1971; Hunter, 1981).

The normal eruption sequence of the permanent maxillary dentition is 6 1 2 4 5 3 7 8 or 6 1 2 4 3 5 7 8 (Hurme, 1949; Lo and Moyers, 1953; Gates, 1963). A tendency towards grouped emergence of teeth has been pointed out by Helm and Seidler (1974) who consider the canine to erupt simultaneously with the second premolar.

From this it is evident that the teeth approximal to the canine are already in occlusion prior to the canine erupting. Furthermore, the canine may be competing for space in the arch with the second molar which may erupt at about the same time (Dewel, 1945). The canine wedges itself into position between the lateral incisor and first premolar, forcing the latter distally to compensate for differences in mesiodistal widths of the canine and first premolar and their deciduous precursors. Its eventual position is slightly buccally placed on the alveolar ridge giving the impression of a "cornerstone" of the arch (Broadbent, 1941; Baume, 1950; Becker, Smith, and Behar, 1981).

## SECTION 3

### THE PALATALLY DISPLACED MAXILLARY PERMANENT CANINE

#### 3.1 DEFINING THE DEFINITION

"Impacted", "unerupted", "ectopic", "embedded", "malposed", "aberrant", "misplaced", and "displaced" have all been used to describe the situation where the maxillary canine has not erupted into its normal position in the arch. "Impaction" infers some physical barrier in the eruption path (another tooth, bone, or soft tissue) that prevents complete eruption (Boucher, 1974; Shafer, Hine, and Levy, 1974). The other terms have been used when the criteria of impaction have not been met, yet the canine remains unerupted and positioned lingually to the other teeth.

Early authors considered the impacted canine to be wedged in the jaw and unable to erupt (Erikson, 1938; Adamson, 1952; Leslie, 1955; Hitchin, 1956; Dachi and Howell, 1961). Later authors (Thilander and Jakobsson, 1968; Aitasalo, Lehtinen, and Oksala, 1972; Gensior and Strauss, 1974) required radiographic and clinical evidence of obstruction for the canine to be considered impacted. Gensior and Strauss (1974) also required a delayed eruption sequence and the unlikelihood of canine eruption (despite a normal pre-eruptive position) even if space is provided in the arch. Ohman and Ohman (1980) use this criterion of no anticipated eruption and add "injury to other teeth" in their definition of "impaction".

Moyers (1973) differentiated between impacted and ectopic (from the Greek word "ektopos" meaning displaced), the latter being deviation from normal in direction or position. "Malposed" (used by Blum, 1923; Bryant, 1924; and Young, 1930) and "aberrant" (used by Newcomb, 1959) are synonyms for "ectopic".

Although Stafne and Austin (1945) used "embedded" as a term, Helmore and Norton (1954) considered that in the majority of cases where the canine has failed to erupt, "unerupted" was preferable. This term is also used by Keith (1945), Kettle (1958), Rayne (1969), von der Heydt (1975), and McKay (1978).

Bass (1967) and Brown and Matthews (1981) considered the canine to be frequently "misplaced" from its rightful position (synonymous with "ectopic"). Rohrer (1929), Howard (1971), and most recently Becker and co-authors (1981, 1984, 1986) have used the term "displaced". Again, this is synonymous with "ectopic" (same etymology), but has the connotation of involuntariness, as if the canine lacks the volition to control its own course of eruption. "Displacement" also does not preclude palatal eruption of the canine into the oral cavity.

No matter which term is used, two essential features withstand - normal eruption of the canine is delayed (and therefore eruption sequence disturbed), and the canine is in an aberrant position in the alveolus.

### 3.2 INCIDENCE

The precise incidence of palatally displaced maxillary canines is difficult to determine from

the literature. Estimates vary from 0 - 3.62% of the community depending on the particular epidemiological study (Mead, 1930; Aitasalo, Lehtinen, and Oksala, 1972). Mulick (1979) attributed this variability firstly, to a lack of criteria for the definition of "impaction", and secondly, to epidemiological studies taken from full-mouth radiographs alone probably only measuring severe impactions.

Many studies, especially early ones, do not differentiate maxillary from mandibular canines, unilateral from bilateral cases, left from right, and occasionally labial from lingual displacement. Some only consider incidence as a percentage of anomalies present and not of the population sample (Blum, 1923; Hitchin, 1956; Dachi and Howell, 1961). Still others don't consider ages or sex distributions (Cramer, 1929; Mead, 1930; Montelius, 1920).

One of the earliest studies of impactions was that of Cryer (1904). He considered the maxillary canine to be second only to the mandibular third molar in frequency of impaction, but based this statement on "experience" rather than objective evidence.

Blum (1923), on the other hand, compiled 457 "malposed" teeth from his practice. Of these, 21.7% were maxillary canines, but no figure is given to relate this to the population sampled.

A survey of 1,000 adult males by Cramer (1929) found 14 cases (1.4%) of canine impaction. Distributions of maxillary/mandibular or buccal/lingual were not reported.

This same year, Rohrer (1929), using his own radiographic localisation technique, made a cross-sectional study of 3,000 German cases (ages unknown). He determined the incidence of impacted maxillary canines as 2.1%. These cases showed a preponderance of 3:1 palatal displacement as against buccal displacement, giving an incidence of palatal displacement of 1.5% in his sample. There was a 5:2 distribution in "favour" of females and a preference to left side impaction (50%) over right side (36%) and bilateral impaction (14%).

Reflecting on the reasons for malposed teeth occurring, Young (1930) believed (subjectively) that only 2% of orthodontic patients had unerupted canines, suggesting a much lesser incidence in the general population. He also believed palatal impaction was three times as frequent as buccal impaction.

Quantitatively, Mead (1930) compared 1,497 Caucasians (white North Americans, ages unknown) to 4,927 multiracial skulls from the Smithsonian Institute, for impactions. While the Smithsonian cases showed no impacted canines (0%), the contemporary cases showed a 1.6% incidence. There were no significant differences between left and right sides, but no differentiation between palatal and buccal, nor between the sexes.

One of the few studies involving non-Caucasians was by Montelius (1932). He erroneously noted a relative infrequency (1:3) of impacted canines in Chinese peoples as compared with Caucasians. His figures are given as percentages of the number of impactions and when computed as percentages of the population groups become 0.5% incidence in Chinese peoples and 0.7% incidence in Caucasians, much

closer than Montelius leads us to believe. No sexual differences were found in the Chinese group, but the Caucasian group showed a 3:2 preference towards females. Age, buccolingual position, and left/right distribution were not identified.

Twenty-four years later, Hitchin (1956) described 109 cases of impacted canines. Of these, 17% were bilateral cases, 83% unilateral. There was a 6:1 palatal preference to buccal, but left/right variations and sex distributions are not mentioned. He does admit that the sample is biased in that the cases were taken from patients attending the Oral Surgery Department of Dundee Dental Hospital (Scotland), the majority of which had had their impacted canines diagnosed as being difficult if not impossible to bring into occlusion.

Dachi and Howell (1961) expressed incidence in terms of canines present because only 244 of the 1,685 cases reviewed from the University of Oregon were between 13 years and 20 years of age - the others were over 20 years of age and showed varying degrees of tooth loss. Their incidence of canine impaction was 0.92% of the cuspids present on radiographs. Correcting this figure to a percentage of the cases reviewed, the incidence becomes 1.66% of which 92% are unilateral (side unknown) and 8% bilateral. The distribution according to sex becomes 4:1 in favour of females, but this may reflect unknown bias in the sample where total sex distribution is not recorded.

An investigation by Nordenram and Stromberg (1966) of 374 Swedish patients aged 9 years to 68 years referred for extraction or uncovering of impacted canines showed a 2:1 female preference, 3:2

palatal to buccal ratio, 67% unilateral versus 33% bilateral incidence, and a slight preference for right side over left side impaction. The large number of buccal impactions is consistent with this being an Oral Surgical study and the biased patient population that usually presents with difficult impactions.

Bass (1967) found that of 9,102 English patients seen for consultation or treatment, 150 (1.65%) had unerupted canines which were treated (ages 10.5 years to 20 years). 45.3% of these canines were on the left side, 38.0% on the right, and 16.7% were bilateral. There was a 2:1 female preference and a 10:1 palatal preference. This makes the incidence of palatal displacement 1.5%.

Another Swedish study, Thilander and Jakobsson (1968) showed that of 384 children (192 boys and 192 girls) studied longitudinally from mean ages 11.5 years to 17.8 years, 5 canines representing 1.3% were unerupted in the palate at the end of the study. No sexual differences could be detected in such a small study and no information is given concerning left/right distribution. A second part of their study was of 49 adults (22 - 36 years old) referred for treatment for impacted canines. 51% of these were palatal impactions with a 2:1 female preference. Slightly more impactions were found on the right side but the sample size is too small to be truly significant.

Rayne (1969) selected 176 patients with impacted canines from 12,000 case records, an incidence of 1.5%. Mandibular canines were included in this figure which when disregarded gives an incidence of 1.36% for maxillary canines. There were no significant differences between right and left side, and 27% of the cases were bilateral

impactions. There was a palatal preference of 5:1 over buccal position, and in the teenage group (12 to 20 years, comprising half the sample group) more females were affected than males. The adult group (over 20 years, comprising half the sample group) showed no sexual differences.

Kramer and Williams (1970) surveyed oral surgery patients in Harlem, New York (a population that is 95% Black). Orthopantomographs of 3,745 patients referred for any reason showed an impacted canine incidence of 1.2%. No sex differences were stated and no other information given.

A Journal of Clinical Orthodontics study in 1970 showed that of 150 reported cases of canine impaction, 13.6% were bilateral and 86.4% unilateral, side unknown. Palatal position showed 6:1 preference.

An orthopantomographic study by Aitasalo, Lehtinen, and Oksala (1972) of Finnish patients between 20 and 69 years of age gave an incidence of 2.95%, but included mandibular canines. Unfortunately, their data is not consistent throughout the article and the incidence of maxillary canine impaction can also be tabulated as 3.62% with females more prevalent (3:2) and left side predominant (53% versus 47% right side).

Thilander and Myrberg (1973) presented an epidemiological study of malocclusion of 5,459 Swedish school children between 7 and 15 years of age. They found an incidence of canine impaction of 2.2% with no differences between sides. In comparison (and not surprisingly) they found that 939 children referred for consultation had a 12.9% incidence of impaction with right side slightly more common than left (only marginally significant,  $0.01 < P < 0.05$ ). Sex distribution is not known for either group.

A cephalometric study of parents of orthodontic patients in Japan was undertaken by Takahama and Aiyama (1982). They calculated the incidence of canine impaction in the general population to be 0.27%. Of these cases, females predominated (5:3) and left side impactions were more frequent than right side. No note is made of palatal/labial position but it is assumed that these are palatal impactions as the study was also in relation to cleft lip and palate. It was also found that parents of cleft lip and palate patients had a higher incidence of impacted canines (1.83%).

Most recently, an epidemiological study by Brin, Becker, and Shalhav (1986) of 2,440 Israeli adolescents aged 14 to 18 years showed an incidence of 1.53%. There were no significant sex differences and no data for left/right distribution. All these canines were palatally positioned.

In summary, palatal impaction (or displacement) of maxillary canines occurs more frequently than buccal impaction and females are more affected than males. With the exception of the Swedish studies, left side impactions predominate, and bilateral impaction may be as high as 33%. Caucasians show a higher incidence of impaction than Blacks or Asians, and a correlation may be present between cleft lip and palate and impacted canines. The average incidence of impaction in the studies cited is 1.49%.

Impaction (all teeth included) is second only to hypodontia as the most common dental anomaly (Thilander and Myrberg, 1973). Of all the

permanent teeth, the maxillary canine is second only to the mandibular third molar in frequency of impaction (Cryer, 1904; Blum, 1923).

### 3.3 RADIOGRAPHIC LOCATION

Prior to the introduction of the x-ray to dentistry at the turn of the century, teeth that failed to erupt were usually considered congenitally absent. Initially, periapical, occlusal, and lateral oblique radiographic views were commonly used and the introduction of the cephalograph by Broadbent (1931) aided in the localisation of unerupted teeth.

The prognosis of surgical - orthodontic treatment of displaced canines depends on many factors. Adequate localisation of the canine(s) is necessary to determine the optimal approach to management of the condition (Bishara et al, 1976; Fournier, Turcotte, and Bernard, 1982).

Radiographs should provide information on location and morphology including:-

- (a) buccopalatal position of the canine crown (and contact, if any, with adjacent teeth);
- (b) position of the root apex (buccopalatal and anteroposterior);
- (c) height of the crown and apex relative to the occlusal plane;
- (d) obliquity of the long axis of the canine;
- (e) morphology of the apex; and

- (f) any pathological condition that may be present (ankylosis, resorption of adjacent teeth, cyst formation, caries, and/or periodontal conditions) (Rayne, 1969; Hunter, 1981).

Radiographic localisation techniques have changed over the years, reflecting changing technology and increasing knowledge and awareness of the inherent dangers of high frequency radiation. Four techniques commonly used are (1) parallax localisation, (2) stereoscopy, (3) panagraphy, and (4) contrasting angle views.

### 3.3.1 Parallax Localisation

This technique uses periapical, occlusal, and panoramic views. Periapical tube-shift was first described by Clark (1910) who originally used three periapical films. Currently, only two films are used, held in the same position as the x-ray tube is shifted horizontally  $20^{\circ}$  -  $30^{\circ}$  between exposures. Similar to this method is the buccal object rule described by Bishara et al (1976) and Richards (1980) which utilises a vertical tube-shift of  $20^{\circ}$  between two successive periapical film exposures. In both these methods, a palatally displaced canine appears to move in the same direction as the tube whereas a buccally displaced canine appears to move opposite to the direction of the tube. Rayne (1969) utilises a periapical film and a true occlusal film for parallax location.

Hitchin (1956) pointed out the problem of using anterior occlusal or true occlusal films in buccopalatal localisation of canines. He believed (and showed) superimposition of canines on adjacent teeth could be misleading and preferred a vertex occlusal film. Although a longer radiation exposure than other occlusal films, this view gives the best information on buccopalatal position.

Panoramic radiography can also be used in parallax localisation provided two important steps are followed. Firstly, the tube and film rotating about the patient's head are stopped (and radiation emission halted) after approximately  $90^{\circ}$  arc has been traversed. The patient is shifted laterally slightly and the procedure is completed through the second arc of  $90^{\circ}$ . This gives two anterior images equivalent to a tube shift. Secondly, because the tube is **behind** the patient, not in front, parallax rules are reversed such that an object moving **with** the tube is **buccal** and an object moving **away** from the tube is **palatal** (Turk and Katzenell, 1970; Hunter, 1981).

Keur (1986) prefers to use the parallax method rather than the vertex occlusal method not only because the former can be performed on standard dental x-ray equipment, but also because it involves less radiation dosage to organs in the head and neck region.

### 3.3.2 Stereoscopy

Stereoscopy is a method of obtaining perspective in radiographs and was advocated by Dewel (1945) for difficult cases. Two anterior occlusal views are taken, one with the tube over the patient's right eye, the other over the left eye. When viewed in a stereoscope there is an illusion of depth (Hunter, 1981). Blum (1923), however, points out the disadvantage "that many operators cannot look through a stereoscope".

### 3.3.3 Panagraphy

A panagraphic x-ray machine (e.g. Status-X) is one which magnifies a panoramic picture via an intraoral tube exposing an extraoral film. The tube emits almost a point source of radiation, giving divergent rays. Objects nearer the source (as a palatally displaced canine would be) are magnified greater than more distant objects (Ostrofsky, 1976). Panagraphic films produce superior results in the anterior region as compared with panoramic films which are better for the posterior segments of the maxilla and mandible. Much shorter exposure times are required for panagraphic films making them suitable for handicapped patients (Keur and Macdonald, 1986).

### 3.3.4 Contrasting Angle Views

In this technique, various standard views are selected to construct a three-dimensional picture. Both intraoral and extraoral views are used and should

include two different planes of space. Most commonly, lateral and posteroanterior cephalometric radiographs are used (Newcomb, 1959; Andreason, 1971; Bishara et al, 1976; Williams, 1981), sometimes in combination with occlusal and periapical films (Hitchin, 1956; Hunter, 1981). Lateral oblique projections have been found useful in that the maxillary canine on the other side can be seen on the profile of the oblique radiograph (i.e. the right oblique radiograph reveals the erupting left canine and vice versa) (Williams, 1981).

The number of contrasting angle views required depends on the clinician's ability to visualise the palatally displaced canine's position. Where there is a sharp apical curve, Seward (1963) recommended up to five views, reminding the operator of the "awkward situation which arises if an attempt to bring a buried canine into the arch fails, or if the removal of a canine proves unexpectedly difficult".

### 3.3.5 Timing

Whether one is screening patients for palatal displacement of canines, or simply suspicious of a developing displacement, radiographic inspection should begin early. Newcomb (1959) and Williams (1981) recommend routine use of posteroanterior and lateral cephalographs from eight years of age. Altonen and Myllarniemi (1976), however, consider the time of eruption of second premolars as sufficient to investigate "suspicious cases".

### 3.4 ASSESSMENT

#### 3.4.1 Signs and Symptoms

Frequently a displaced canine will displace a lateral incisor from its normal position and produce a marked rotation and/or tipping which is often the first symptom of which a patient complains. If the deciduous canine is present, it is often not realised that it is deciduous and not permanent and a radiograph may be required to verify this to the patient and parent. If the deciduous canine is lost and the permanent canine unilaterally palatally displaced, shift of the midline to the affected side may be obvious and unesthetic to the patient (Fastlicht, 1954; Gensior and Strauss, 1974).

Pain is not always a feature but may be present either locally, or neuralgic in character. Such pain may refer to the eye, ear, side of the head, entire side of the face, back of the head, or the shoulder on the affected side (Kronfeld, 1939; Hitchin, 1956). Chronic headaches, intractable insomnia, and frontal headaches with vague flashes of pain of equally vague origin have all been reportedly cured by removal of palatally displaced canines (Blum, 1923; Field and Ackerman, 1935; Quinn, 1951).

Pressure on unerupted teeth may cause simulated periodontitis which may be aggravated by traumatic occlusion. Such pain is dull and constant, and severe cases show increased tooth mobility (Rohrer,

1929; Hitchin, 1956). Pressure from unerupted canines has also been implicated in "functional nerve involvement" which in some cases may predispose to serious nervous and mental disturbances such as epilepsy, chorea (ceaseless, rapid, jerky, involuntary movements), dementia precox (schizophrenia), mental fatigue, amblyopia (dimness of vision without detectable organic lesion of the eye), psychasthenic states (feeble-mindedness), and sneezing (Gunter, 1942).

Pericoronitis associated with canines is rare, as is cellulitis of the face arising from pericoronitis of the canine. This may be due to "dependent drainage to any partially erupted canine" and the distance of the canine from the main muscles of mastication (Hitchin, 1956).

Clinically, early detection of aberrant canine eruption is in the hands of the general dental practitioner. At 8 years of age, routine examination should include palpation of the labial surface of the maxilla above the deciduous canine. A normally developing permanent canine will be felt in the sulcus as a diffuse bulge, quite different to the vertical ridge which overlies the deciduous canine root. As the deciduous tooth resorbs, the canine bulge moves occlusally. If at 10 years the vertical ridge of the deciduous root is still palpable, palatal deflection of the canine should be suspected. Occasionally the root apex of the palatally displaced canine can be palpated above the first premolar crown (Rayne, 1969; Gensior and Strauss, 1974).

Sometimes a displaced canine can be palpated palatally but the firmness and irregularity of the fibrous connective tissue of the palatal rugae can make this examination deceptive (Hartley, 1956; Moss, 1971, 1975).

Observations of the relative positions of the first premolar and lateral incisor will help to identify the position of the canine. A lateral incisor that is tipped or rotated may have the canine crown tip pressing against its root apex. Similarly, a canine apex lingual to a first premolar will tip its crown lingually, and a canine apex buccal to a first molar will tip its crown buccally (Rayne, 1969; Moss, 1971, 1975).

Prolonged retention of one or both deciduous canines is a prime sign of abnormality in the canine region (Gensior and Strauss, 1974). Other signs include mobility of teeth (usually caused by root resorption of incisors by palatal canines) and loss of vitality (Hitchin, 1956; Rayne, 1969; Moss, 1971, 1975). Chapman (1983) and Becker and co-authors (1981-1986) advocate screening patients with aberrant lateral incisor morphology as these patients show higher incidences of palatally displaced canines (see Section 3.5.1.7).

Hitchin (1956) also suggests an occlusal examination may be necessary for two reasons. Firstly, because palatally displaced canines may be an etiological factor in some cases of cuspal

interference, and secondly, because there are cases where the palatal canine is acting as a buttress against which a hyperfunctional tooth is taking a marked occlusal load.

#### 3.4.2 Classification

Displaced maxillary canines have been classified, albeit arbitrarily, according to their position in the maxilla. Several authors have presented classifications (Field and Ackerman, 1935; Adamson, 1952; Helmore and Norton, 1954; Leslie, 1955; Baden, 1956; Hitchin, 1956; Thoma, 1963). Except for minor personal embellishments by the other authors, the classifications of Field and Ackerman (1935) and Adamson (1952) still stand.

Field and Ackerman categorised the canine firstly in the frontal plane according to crown position - palatal, labial, or intermediate (as did Rohrer, 1929) - and then cross-referenced the crown position against the roots of the standing teeth in the horizontal plane.

Adamson's approach was made according to the horizontal position of the canine, and again seems to be a flow-on from the work of Rohrer (1929). Group 1 canines are vertically positioned, either labial or lingual, and have the best prognosis for eruption after exposure. Group 2 canines are lingually positioned, deeper, and more obliquely situated. They may need positive traction to aid eruption. Group 3 canines are horizontal in the palate and will not erupt spontaneously even with exposure.

### 3.4.3 Characteristics

As well as forming the basis of the above classifications and giving information on incidence and distribution of canine displacement, Rohrer (1929) also described certain characteristics of displaced canines. Tooth follicle could not be detected in 26% of his sample. 64.4% showed normal follicles and 9.6% were enlarged or cystic. Bilateral palatal displacement showed lack of symmetry in position.

Rotation was a frequent occurrence (45% of the cases). Rotations less than  $45^{\circ}$  about the longitudinal axis were not common whereas 37% of the sample had rotations between  $60^{\circ}$  and  $90^{\circ}$ . Thilander and Jakobsson (1968) also found many unerupted canines in both their adult and adolescent groups to be rotated up to  $90^{\circ}$ . The majority of palatally displaced canines were found to be rotated mesiopalatally when they erupted (Rayne, 1969).

Studying autogenous transplants, Rohlin and Rundquist (1984) found it necessary to rotate the canine during surgery (inferring that all fifty-five canines in their sample were rotated).

Looking at the sagittal position of the canines in his study, Rohrer (1929) found 19% in normal position, 48% in oblique position, and 33% horizontal (equivalent to Adamson's Groups 1, 2, and 3 respectively). This frequency distribution has been verified by other authors (Marsh, 1965;

Cranin and Cranin, 1968; Rohlin and Rundquist, 1984). Marsh (1965) also suggested that horizontal positioning of the canine occurred due to continued growth of the root.

Dewel (1945, 1949b) and Fastlicht (1954) noted, with curiosity, a tendency for palatal canine displacement to appear in mouths which otherwise present quite normal arch form and occlusion of the teeth, and with almost enough room to accommodate them in their normal positions. Bass (1967) verified this when he found 24.7% of his impacted canine cases had the displaced canine as the sole malocclusion present. In fact, 30.0% of his cases had no crowding in the maxillary arch (see Section 3.5.1.8).

Rohlin and Rundquist (1984) drew attention to the presence of a deflected root apex in 57% of their impacted canine cases, deflection being mainly in the buccal direction. Seward (1963) and Rayne (1969) only briefly mention "recurvature" of the canine apex and Gunter (1942), Lappin (1951), and Azaz and Shteyer (1978) each illustrate a case with deflection of the apex without noting it in the text. Rohlin and Rundquist (1984) suggest the apical deflection is a result rather than a cause of canine impaction, due mainly to the plastic nature of a developing root and the constricted space available for it in trabecular bone, limited by the cortical linings of the nasal cavity, maxillary sinus, and anterior border of the maxilla.

### 3.5 ETIOLOGY

An unwritten law in general medicine is "that to know the cause is half the treatment". This law also applies to the treatment of dental and skeletal anomalies. As early as late last century E. S. Talbot believed that without a knowledge of etiology, no-one can successfully treat and correct anomalies (Weinberger, 1919).

The etiology of palatally displaced canines is confused, obscure, and controversial. The actual etiology appears to be unknown. Jacoby (1983) claims that the literature rarely mentions etiological factors of canine impaction and that most authors merely repeat the same references. Despite this claim, a multitude of authors have presented a large number of etiological factors - some original, some repetition, some mere speculation based on "logic". No-one has suggested a definitive etiological factor, nor is it likely that one exists. Rather, it is probable that several factors work together and by their peculiar circumstances produce a palatally displaced canine.

Typically suggested factors include developmental and anatomic variations, mechanical obstructions, trauma, local pathosis, systemic disease, and heredity, and for convenience will be discussed as local and systemic etiological factors.

#### 3.5.1 Local Etiological Factors

##### 3.5.1.1 Eruption Pathway

Dewel (1945, 1949b), believed that the original cause of canine displacement lay in the extent of eruption required.

"Opportunity for deflection from a normal course increases in proportion to the distance a tooth must travel from its area of development to full occlusion" (1945). Because it develops at a much higher level than other teeth, the canine has a much greater opportunity for directional deviation than teeth that develop closer to the surface. This concept of a "long and tortuous" eruption pathway is iterated by other authors (Lappin, 1951; Helmore and Norton, 1954; Baden, 1956; Gensior and Strauss, 1974; McBride, 1979; Mulick, 1979).

Concomitant with the length of the eruption pathway is the long time of eruption. Despite beginning to develop at about the same time as the central incisor, the canine takes twice as long to achieve complete eruption and is therefore much more susceptible to unfavourable environmental influences (Dewel, 1945, 1949b; Gensior and Strauss, 1974).

The canine is the last of the successional dentition to erupt. The lateral incisor and first premolar have already assumed their places and the canine must accept whatever space is left (Lappin, 1951). It replaces a tooth smaller in width than itself (unlike the premolars whose deciduous predecessors are broader) and must wedge itself between teeth already established in occlusion.

From its high developmental position, the canine must move mesially and occlusally in its eruption. Any local factor that acts to change the axial inclination of the canine may deflect it from its normal pathway. Such a deflection would take the canine further mesially than normal leaving it palatal to the lateral incisor root (Lappin, 1951; Miller, 1963; Thilander and Jakobsson, 1968; Moyers, 1973).

### 3.5.1.2 Displaced Tooth Germ

Young (1930) first suggested ectopic teeth to be the result of "malposed tooth germs", although he presents no data to defend this statement. His thoughts, however, are repeated through the literature (Cranin and Cranin, 1968; Moyers, 1973; Bishara et al, 1976; Mulick, 1979).

Moyers (1973) and Cranin and Cranin (1968) include rotation of the tooth bud as an etiological factor, believed by Richardson and McKay (1983) to be hereditary in nature. A rotated tooth bud (rotated about any axis, not just the longitudinal axis) will erupt along its long axis but may be "targetted" in the wrong direction because of the rotation (Schafer, Hine, and Levy, 1974).

Hitchin (1956) suggested that the bulbous nature of the canine crown may place the cusp tip more deeply palatally, thereby increasing the chance of palatal deflection. In contrast, Le Bot and

Salmon (1977) noticed a decrease in crown dimensions of canines in cases of aberrant (reduced) or missing lateral incisors (see Section 3.5.1.7). From this it could be argued that a canine that has a relatively smaller crown size may nestle high in the maxilla and then emigrate too far mesially and trap itself palatally to the lateral incisor root.

### 3.5.1.3 Deciduous Canine

The developmental position of the permanent canine on the palatal aspect of the deciduous canine root has lead this tooth to be blamed for deflecting the permanent canine palatally. Any change from the normal exfoliation pattern of the deciduous canine has been claimed to be reflected along the full length of the root and cause deviation in position and growth of the permanent canine tooth bud (Johnston, 1969). Over-retention, peri-apical pathology, and premature loss of the deciduous canine have all been implicated.

Retained deciduous teeth have long been held responsible for unerupted teeth (Angle, 1910; Cryer, 1911). Dewel (1945) may have been the first author to apply this concept specifically to the canine, basing his theories on the histological study by Logan and Kronfeld (1933) and the radiographic study by Broadbent (1941), both of which showed the various developmental positions of the canine relative to the deciduous canine root. Dewel's theories have been

repeated without further qualification (sometimes verbatim) by many other authors (Fastlicht, 1954; Helmore and Norton, 1954; Leslie, 1955; Baden, 1956; Hitchin, 1956; Kettle, 1958; Adelman, 1969; Johnston, 1969; Lewis, 1971; Moyers, 1973; Bishara et al, 1976).

A reason for this may be lack of understanding of the resorptive process involved in exfoliation of deciduous teeth. Ten Cate (1976) points out that the mechanisms involved in the initiation of tooth resorption are not fully understood, but that pressure from the erupting successional tooth plays a key role in differentiating odontoclasts at sites of pressure. The other major factor involved is the increased forces accruing from the growing muscles of mastication which cause pressure and trauma to the deciduous periodontal ligament, also causing resorption. This explains why resorption can be seen on deciduous roots of teeth without successors (but usually many years after the normal exfoliation age).

Early authors believed resorption of deciduous teeth was an autonomous event, and if delayed in its onset could cause the developing crown to be deflected by an intact deciduous root. Thilander and Jakobsson (1968) and Moss (1971) gave credence to the thought that a retained deciduous canine was the result, not the cause, of a palatally displaced canine. The possible exception to this may be actual ankylosis of the deciduous canine (Baden, 1956; Cranin and Cranin, 1968).

Periapical pathology associated with the deciduous canine (e.g. chronic granuloma, chronic focal sclerosing osteomyelitis, or radicular cyst) may delay root resorption of the deciduous canine and cause palatal deflection of the permanent canine. Caries exposing the pulp, or trauma are the usual causes of these conditions, although deciduous canines are not as susceptible to caries as other teeth, nor as vulnerable to trauma - the incisors usually taking the brunt of accidental blows (Erikson, 1938; Fastlicht, 1954; Hitchin, 1956; Kettle, 1958; Cranin and Cranin, 1968; Thilander and Jakobsson, 1968; Johnston, 1969; Moss, 1975; Richardson and McKay, 1983).

Premature loss of the deciduous canine (including "serial extraction" procedures) can allow the first molar to migrate mesially (with the entire buccal segment), shortening the arch length and reducing the available space for the permanent canine to erupt. It may then be diverted either labially or palatally (see Section 3.5.1.8) (Dewel, 1945; Fastlicht, 1954; Baden, 1956; Hitchin, 1956; Cranin and Cranin, 1968; Adelman, 1969; Johnston, 1969).

#### 3.5.1.4 Obstructions

The follicular space surrounding palatally displaced canines is often found to be enlarged. Distinction between enlargement and cystic change is arbitrary, and Rohrer (1929) considered

9.6% of his cases to have enlarged follicles or dentigerous cysts. Thilander and Jakobsson (1968) thought this incidence to be much higher (50-75%), but could not conclude it was the cause of palatal displacement.

Erikson (1938), Fastlicht (1954), Lewis (1971) and Moss (1975) simply mention cysts as an etiologic factor in canine displacement, but it was Kettle (1958) who elucidated the reason for its inclusion. He believed there is a cushioning effect of the enlarged tooth follicle or cyst that removes the guiding influence of the adjacent teeth (especially the lateral incisor). Fairley (1953) has illustrated the extreme case of a dentigerous cyst causing canine displacement into transposition with the first premolar.

Odontomas, supernumeraries, tumors, dense palatal tissue, and fibrous scar tissue have been put forward as mechanical obstructions that may prevent or divert canine eruption (Erikson, 1938; Dewel, 1945, 1949b; Lappin, 1951; Helmore and Norton, 1954; Baden, 1956; Hitchin, 1956; Kettle, 1958; Cranin and Cranin, 1968; Di Biase, 1971; Lewis, 1971; Moss, 1971, 1975).

All authors agree that supernumerary teeth, odontomas, and tumors are rare in the canine region, and are included as extenuating factors. Dewel (1945) and Hitchin (1956) believed the reason that canines, once they are displaced

palatally, do not erupt, is due to the more fibrous nature of the palatal mucosa and the denser bone of the palate as compared with the alveolar ridge.

Scar tissue formation from an exposure that has closed, or epithelialization and reorganisation of tissues following loss of the deciduous canine can leave a tough, fibrous mucoperiosteum overlying the permanent canine which may delay eruption or divert the eruption path (Burke, 1954; Cranin and Cranin, 1968; Johnston, 1969; Di Biase, 1971).

#### 3.5.1.5 Trauma

Trauma to a developing tooth germ via injury to the primary tooth has been considered an etiological factor in tooth impaction (Adelman, 1969; Moyers, 1973; Bishara et al, 1976). Baden (1956) believed trauma to be the exception in canine displacement and Moss (1975) considered it more of a factor in central incisor impaction and dilaceration of the root. Trauma to the periodontium of the erupting tooth may retard eruption (Cranin and Cranin, 1968), but palatal displacement of the canine has usually already occurred by the time this can happen. Scar tissue from previous trauma may also prevent eruption as discussed in Section 3.5.1.4.

#### 3.5.1.6 Retarded Development and Eruption

Factors, whether environmental or genetic, which retard development in the

canine region, or influence the mechanism of bone growth deleteriously may precipitate displacement of the canine (Gunter, 1942; Dewel, 1945, 1949b; Adamson, 1952). The effect of these factors may be to retard tooth development, delay eruption, or give rise to an abnormal eruption sequence.

Newcomb (1959) considered "with few exceptions", that potential canine impaction patients exhibited moderate to severe retardation of dental maturity - i.e. a slow rate of permanent tooth development and retarded exfoliation of the deciduous teeth.

Development of the canine relatively close to a growth centre in the maxilla can result in retarded eruption if growth is disturbed in some way (Leslie, 1955). Garn, Lewis, and Vicinus (1963) have noted a delay in the developmental timing of teeth in cases of third molar agenesis, but this could not be verified by Le Bot and Salmon (1977). Apparently there have been no studies to correlate agenesis of third molars and canine displacement as related to tardy development of teeth and eruption.

That an abnormal eruption sequence may displace the canine was suggested by Dewel (1945) who noted that the second molar begins its eruption at approximately the same time as the canine. He believed that forward drift of buccal segments with eruption of the second molar could crowd the canine into

palatal displacement and thereby exacerbate an already delayed eruption by the obstruction of the denser hard and soft tissues of the palate.

Thickening of the tooth follicle (frequently found with impacted canines) may be responsible for failure to erupt, as could pathosis of the mucous membrane (Stoy, 1954; Di Biase, 1971). Young (1930) and Moyers (1973) also mention premature root closure of the canine may prevent its eruption since most of its root development occurs before clinical eruption.

#### 3.5.1.7 Lateral Incisor

Possibly the first authors to mention congenital absence of lateral incisors in relation to palatal canine displacement were Kettle (1958) and Miller (1963). Both noted that instead of simplifying eruption of the canine (due to the absence of permanent teeth to crowd out the tooth), the guiding influence of the lateral incisor root was missing and the course of canine eruption more uncertain. Frequently the deciduous canine root acts as a guide plane to deflect the permanent canine either mesially against the central incisor root, or palatally. Miller (1963) describes the canine in this case to take "the path of least resistance".

Bass (1967) recorded a raised general level of tooth agenesis, particularly lateral incisors, in his displaced canine

group, suggesting that both missing teeth and palatally displaced canines "are caused by the same minor disturbance of the dental lamina". This may also be the reason Le Bot and Salmon (1977) found decreased crown dimensions in canines (especially buccolingually) in cases with aberrant or missing lateral incisors.

Interestingly, some authors (Sly, 1950; Lappin, 1951; Fairley, 1953; Baden, 1956) have illustrated cases of palatal canine displacement prior to Kettle (1958) with radiographs that clearly show the lateral incisor on the side of the canine displacement to be missing. None mention this in their texts.

Hitchin (1956) considered a more labial than normal position of the lateral incisor in some cases to be "the primary abnormality" that allowed the canine to be more easily deflected palatally. Only relatively recently has the incidence of peg-shaped or morphologically small lateral incisors definitively been linked with palatal canine displacement (Becker, Smith, and Behar, 1981; Chapman, 1983; Becker, 1984; Brin, Becker, and Shalhav, 1986). Of 128 palatally displaced canine cases studied by Becker, Smith, and Behar (1981), only 50% had a normal lateral incisor adjacent, the rest being small, peg-shaped, or missing, in that order. This finding has been confirmed by Chapman (1983).

A link between crown size and root size of lateral incisors was uncovered by

Becker, Zilberman, and Tsur (1984). They found a small lateral incisor crown to reflect a small root, and that small lateral incisor roots were linked with the incidence of palatally displaced canines. This is contrary to the beliefs of Miller (1963) who thought that peg-shaped lateral incisors had normal roots and could guide the eruption of the canine in the normal manner.

Teeth with small mesiodistal dimensions have been found to develop late (Garn, Lewis, and Vicinus, 1963; Sofaer, 1970). This, along with their own findings, has made Becker, Zilberman, and Tsur (1984) conclude that the short length of the lateral incisor root is more likely the critical factor, together with late development, in depriving the canine of its correct eruptive guidance. Brin, Becker, and Shalhav (1986) computed the probability of finding a palatally displaced canine next to a normal lateral incisor as 0.98%, next to a small lateral incisor as 9.80%, a peg-shaped lateral incisor as 11.50%, and an absent lateral incisor as 5.00%.

As was the case with absent lateral incisors, authors have illustrated cases of palatal canine displacement with small or peg-shaped lateral incisors without commenting on their presence or possible role in etiology (Fastlicht, 1954; Brown and Matthews, 1981). Di Biase (1971) even shows a case with a peg-shaped lateral incisor adjacent to a palatally displaced canine, and a missing lateral

incisor with normal canine eruption, without comment on either anomaly.

#### 3.5.1.8 Dentoalveolar Relationships

From the writings of John Tomes in 1847 (Weinberger, 1916) to the present day, crowding of the maxillary arch has been considered the major etiological factor in palatal displacement of the canine. None of the authors give actual evidence of crowding in the arch as being primary to canine displacement. Most either repeat the works of others, quote from "experience", or apply "logic" to solve the problem. There is certainly a paucity of studies to quantify this enigma.

The theory of deficient space in the maxillary arch for the canine to erupt has been extolled by authors such as Erikson (1938), Baden (1956), Di Salvo (1971), Moyers (1973), Gensior and Strauss (1974), Howard (1978), Mulick (1979), and Fournier, Turcotte, and Bernard (1982), but without supporting evidence. Fastlicht (1954) agreed with these authors but noted some cases with well developed arches (exceptions to his general rule).

Narrow arches, particularly in the canine region, increased overbite and retroclination of the maxillary anterior teeth, and generalised lack of space were thought by Kettle (1958) to cause palatal canine displacement. Curiously, he includes missing lateral incisors as

an etiological factor without commenting on the extra space that must be available in the arch for the canines to erupt, maintaining crowding to be the primary factor.

The conclusion of McBride (1979) was that failure of eruption of the maxillary canine was **not** so affected by crowding as its counterpart, the mandibular canine.

A few early authors did not agree that crowding was a factor in canine displacement into the palate. Young (1930) realised "strange as it may seem, it is rare to find such teeth (palatally displaced canines) in very underdeveloped arches. The vast majority of such cases have been found in patients with good dental arch development, with almost sufficient space to accommodate these teeth when brought into position".

This notion is iterated by Dewel (1945, 1949b) and Helmore and Norton (1954) who believed that neither crowding nor contracted arches were important factors. Lappin (1951) claimed clinical data that proved Dewel's comments, but did not publish it, and Lewis (1971) reported cases of palatal canine displacement with adequate space in the arch to accommodate the canine.

Richardson and McKay (1983) found palatally displaced canines in arches that were "broad and generous, where the incisors are not retroclined and where there has been no premature loss of

deciduous teeth". They consider crowding to be not the only cause of "delayed eruption" of canines, "nor is it even an important factor judging by the large number of crowded cases which do not have delayed eruption of canines". Their paper is illustrated with examples of different arches with displaced canines, but without systematic quantification. One important point they make, however, is that in crowded arches it is much more common to find the canine erupted on the buccal side of the arch, frequently overlapping the lateral incisor. This confirms the findings of Thilander and Jakobsson (1968).

In refuting crowding as an etiological factor in palatal displacement of canines, Jacoby (1983) found 85% of his sample of forty palatally displaced canines to have sufficient space for eruption in the dental arch. Five buccally displaced and unerupted canine cases all showed arch length deficiency. He also noted from measurements taken on orthopantomographs that the distance across the maxilla measured from the nasal cavity to the sinus cavity was greater on the palatally displaced side than on the labially erupted side. How he actually takes these measurements is unexplained, but the conclusions drawn are that arch length deficiencies produce labial rather than palatal displacement of the canine. Palatal displacement occurs when there is extra space available in the maxillary bone at the basal bone level. This can be provided

by excessive growth in the base of the maxilla, agenesis of/or peg-shaped lateral incisors (Section 3.5.1.7), or "stimulated eruption" of the lateral incisor or first premolar. Class II, Division 2 cases may show mild crowding but may have extra space present at the basal bone level.

This last point was taken up by Mew (1984) who still thought crowding to be the important factor in palatal canine displacement, but conceded that it is space available in the area between the roots of the lateral incisor and first premolar (and not between the crowns) that may allow the canine to displace itself palatally.

#### 3.5.1.9 Evolution and Heredity

Historically, evolution is included as an etiological factor. The forces of human evolution take so long to come to fruition that it is beyond one person's lifetime to study them. Early authors were quick to pick up the post-Darwinian fervour and include evolution, or perhaps more correctly "involution" (Mead, 1930) as contributing to palatal displacement of the canine.

Deficient mastication has occurred in modern times due to the increased consumption of processed foods. This soft diet, as compared to the hard diet encountered in less civilized races, has lead to a lack of function of the masticatory apparatus, a factor Fastlicht

(1954) believed to influence lack of development of the maxilla. In addition, increased consumption of complex carbohydrates and especially confectionery goods saw caries become an important factor in the etiology of malocclusion.

Mead (1930) recognised that the masticatory apparatus of Modern Man was undergoing atrophic changes reflected in the dentition. He saw the cranium, which once had to provide much wider attachments for masticatory, neck, and trunk muscles in Primitive Man, as throwing off the remnants of masticatory function. This effect was seen more on the molars (governed by the temporalis muscle) than on the anterior teeth (governed by the masseter muscle.)

Gunter (1942) believed the teeth had been reduced in number and size at a lesser rate than the jaws, in particular the alveolar processes. He noted studies of Eskimos (as did Mead, 1930) that had shown urbanisation effects in later generations. Marked deterioration in the size and strength of the jaws and in irregularities of the teeth after adoption of a "modern" diet and mode of living were seen in the first generation. This showed how form, quality, and size of the alveolar processes are dependent on function.

Lack of a coarse diet has been cited by Begg and Kesling (1977) as the major factor leading to malocclusion in Modern

Man. The decrease in attritional occlusion is seen to fall out of synchrony with mesial migration of the teeth resulting in malaligned teeth.

Given these apparent evolutionary (or involutionary) trends towards reduction of jaw size, one would expect the frequency of tooth impaction to be increasing unless tooth size reduction keeps pace with the jaws. This point is conjectural, however.

\*

Heredity is the nostrum of evolution. Evidence of inheritance of human facial features is universally accepted. Jaw size is determined largely by heredity but the modes of transfer are unresolved. The inheritance of large teeth from one parent and small jaws from the other was an early suggestion for the cause of malocclusion and tooth impaction as it was known that malocclusion occurred frequently in the same family (Gunter, 1942).

Early authors such as Erikson (1938) claim heredity as the "only apparent factor" in canine displacement from observing cases "where without crowding or other cause apparent, the same tooth has been found impacted in child and parent alike". Familial patterns of palatal canine displacement have been recorded in parent and child, amongst siblings, and amongst cousins (Lappin, 1951; Leslie, 1955; Lewis, 1971;

Richardson and McKay, 1983). These authors concluded canine displacement to be hereditary or congenital in nature.

Cranin and Cranin (1968) and Thilander and Jakobsson (1968) list heredity as an etiological factor, but Moyers (1973) doesn't consider it of major concern. Strangely enough, the Journal of Clinical Orthodontics Practice Problem Study (1970) found no family histories of canine displacement. This was thought to be highly significant, but remains the only study to make this claim.

Adelman (1969) thought that the family pattern of canine displacement sometimes found illustrated the role of genetics in this problem. Unfortunately, he does not expand on this point. Moore (1944), however, described sixteen traits of malocclusion that he had shown to be hereditary in nature. Among these are asymmetries, jaw size and arch form, absence or malformation of teeth, crowding or spacing, rotations, axial inclinations of the anterior teeth, and anteroposterior displacement of the apical bases. All of these have been described as local factors in the etiology of palatal canine displacement (Section 3.5.1).

In his review of the literature on inheritance patterns, Graber (1978) came to the conclusion that congenital absence of teeth in some cases appeared to be a form of a more generalised congenital

disturbance, particularly one of the ectodermal dysplasia syndromes. This may explain the three generation case pedigree of palatal canine displacement and tooth agenesis (other than third molars) described by Lewis (1971). These factors made Richardson and McKay (1983) suggest palatal canine displacement to be part of an hereditary syndrome, one that shows an autosomal dominant pattern with incomplete penetrance and variable expressivity.

### 3.5.2 Systemic Etiological Factors

Systemic etiological factors play a far more nebulous role in canine displacement. Systemic factors may relate to endocrinopathies, syndromes, and developmental anomalies.

#### 3.5.2.1 Endocrinopathies

Endocrine disturbances have been known to retard dental maturation and tooth eruption and have often been included in lists of "other causes" of palatal canine displacement (Gunter, 1942; Fastlicht, 1954; Thilander and Jakobsson, 1968; Rayne, 1969; Bishara et al, 1976). Newcomb (1959) has noted a delayed dental maturation in displaced canine cases but does not speculate on the cause of this characteristic.

Dental anomalies may occur if an endocrinopathy is encountered prior to adolescence (Gunter, 1942). Hypothyroidism and pseudohypoparathyroidism are the

major endocrinopathies that influence tooth impaction. Thyroxin is the factor that stimulates tooth size and eruptive movement but has little effect on alveolar growth. Growth hormone secreted in the pituitary gland increases dental and alveolar growth but has little effect on the rate of eruption. Other endocrine glands may also affect tooth development and eruption by influencing metabolic interrelations (Shafer, Hine, and Levy, 1974).

### 3.5.2.2 Developmental Anomalies

This category of etiological factors is an omnium gatherum of observations that may be influential in canine displacement, or merely secondary to the event. "Syphilis, tuberculosis, malnutrition, rickets, anemias, exanthemas of childhood, endocrine dysfunctions, cleidocranial dysostosis, oxycephaly, progeria, achondroplasia, and a score of other diseases have been rightly or wrongly accused of causing impaction of permanent teeth" (Baden, 1956). These conditions are thought to create a favourable situation for mechanical obstruction by arresting bone growth either temporarily or permanently. Cryer (1911) believed that impactions were symptoms of these pathological disturbances, but Baden (1956) considered systemic disease more likely to be a secondary factor in impaction.

Other authors (Cranin and Cranin, 1968; Thilander and Jakobsson, 1968; Rayne, 1969; Moss, 1971; Moyers, 1973; Bishara et al, 1976) have also added systemic diseases to their lists of etiological factors, mainly for completeness, but without elaborating on the mode of action. Malnutrition and hypovitaminoses (particularly vitamin D deficiency as it relates to bone formation) have been specified as contributing to impaction, but again without clarification. Only Leslie (1955) qualified his inclusion of illness or febrile systemic disturbance by explaining that "the canine segment of the maxilla is closely related to a growth centre" (not defined), and that a lack of growth in this segment for the aforementioned reasons may result in retarded eruption and impaction even if the rest of the arch is in good occlusion.

Leslie's "growth centre" is most probably the premaxillary suture between the maxillary and premaxillary bones. Young (1930) noted that the usual place for the canine to develop was just posterior to this suture and towards the labial surface of the maxilla. However, it is questionable whether this "suture" exists in Man beyond the foetal growth stage as it becomes the incisive fissure in the new-born (Bhaskar, 1976).

Rohrer (1929) placed the canine "at the limit of the maxilla and intermaxillary bones" and suggested differences of

growth at this site may easily displace the canine. This thought is iterated by Dewel (1945) and subsequently by Hitchin (1956) and Rayne (1969), but with the conclusion that there is no evidence to support this contention. More recently Takayama and Aiyama (1982) considered "incomplete fusion of the suture line between the incisal and maxillary bones, or the remnants of the suture tissue may result in an arrest of upper canine eruption", This, however, is only speculation.

Growth of the piriform aperture by resorption of the lateral walls was shown by Broadbent (1941) to be necessary to increase the subnasal area and allow downward, forward, and lateral movement of the canines in normal eruption. There are two distinct increments of growth (measurable across the intercanine distance), one coincident with eruption of the central incisors, and the other coincident with eruption of the canines (Lewis, 1936; Leslie, 1955; Sillman, 1964).

Dewel (1945, 1949b) has previously noted (albeit a single case report) "an underdeveloped right nostril, this on the same side as the deeply impacted canine". The atlas compiled by van der Linden and Duterloo (1976) also shows more than one skull with a lingually displaced canine and an asymmetry of the piriform aperture. This asymmetry is manifested by a shallower contour of the infero-lateral bony margin of the piriform

aperture on the same side as the affected canine, and is probably the result of defective resorptive remodelling in this region during the period of increase in piriform aperture size. The result is that the developing canine on the affected side is sitting in a greater volume of bone than the canine on the non-affected side. This is consistent with the findings by Jacoby (1983).

The other developmental anomaly that influences canine eruption is cleft lip and palate. Rayne (1969) and Bishara et al (1976) included this as a local disturbance that may deflect the canine palatally, even into the cleft. Takayama and Aiyama (1982) have gone as far as to consider palatal canine displacement to be a microform of cleft lip and palate. This is based on their findings of a higher incidence of canine displacement in parents of cleft lip and palate patients compared with parents of a non-cleft control group of orthodontic patients in Japan.

Comparison of certain characteristics of palatally displaced canines and clefts proves interesting. Most studies found that canine displacement occurred more frequently on the left side than on the right (Section 3.2). Fogh-Anderson (1961) determined the preferential side for unilateral cleft lip and palate to be the left (2:1). He also found males more commonly affected than females (except for cleft palate alone which is more common in females), the reverse of the

canine displacement situation where females predominate. Absence of lateral incisors (sometimes associated with palatally displaced canines) was suggested by Woodworth, Sinclair, and Alexander (1985) to represent incomplete expression of a cleft, or even part of a larger craniofacial anomaly. This is similar to the hereditary syndrome concept of canine displacement by Richardson and McKay (1983). It might also be worthwhile to note here that the recently reintroduced technique of bone grafting of alveolar clefts just prior to anticipated canine eruption seems to favour tooth eruption, particularly canines which will migrate into the bone graft (Troxell, Fonseca, and Obson, 1982).

### 3.5.3 Summary

Generally stated, each malocclusion probably results from at least two sets of factors, one physiologic, the other environmental (Mead, 1930). This is complicated by the wide range of differences in development of individuals, even those with apparently similar health, diet, habits, and rates of growth.

In the case of palatal canine displacement, several factors may be found singly or together which can otherwise be present in normal occlusions. The problem is that it is extremely difficult to prove that a particular factor is relevant to the

etiology generally, whether it is specific to the particular case in hand, or if it is only secondary to some other, possibly unknown, factor.

For this reason, the etiology of the palatally displaced canine remains obscure with many contemporary orthodontists more content to treat the affected adolescent than to attempt prevention in the pre-adolescent. If the etiology could be clarified, then secondary preventive measures aimed at correcting an aberrant eruption path of the permanent canine (interceptive orthodontics) could be deployed.

Etiological factors most important in palatal displacement of the canine are the distance and lengthy time of eruption, ectopia of the tooth germ (usually rotation), aberrant morphology or absence of the lateral incisor root, and the amount of space in the maxillary basal bone during canine development (and **not** crowding of the teeth). That these factors can be inheritable may suggest palatal canine displacement could be an hereditary condition and explain familial patterns. Further investigation into any relationship with clefting or agenesis of lateral incisors could prove beneficial, but not as much, perhaps, as a study to determine the influence of piriform aperture growth changes in relation to the area of canine development.

### 3.6 SEQUELAE

Palatally displaced canines occasionally erupt late in life (late teens or early twenties - rarely any older). Gunter (1942) considered this common after loss of adjacent teeth, but Bass (1967) found record of eruption palatal to the deciduous canine in intact arches. This "sudden" emergence of a tooth in the palate can be of great concern to a mature patient who has often not been previously concerned about any malocclusion present. A condition of partial eruption can then occur and be maintained, whereupon caries and pericoronal inflammation may develop.

Follicular (dentigerous) cysts can carry a canine quite a distance from its normal position (as far as the floor of the orbit). Bone destruction caused by the cyst may make retrieval difficult and progression of the cyst to ameloblastoma can occur (Shafer, Hine, and Levy, 1974).

The most frequent and perhaps most important of the sequelae of palatal canine displacement are resorption of the canine and resorption of neighbouring (impinged) teeth (Fastlicht, 1954; Shafer, Hine, and Levy, 1974). Whilst one or more sequelae may be found, it is common to find no untoward effects in the lifetime of an individual (Bishara et al, 1976).

#### 3.6.1 Resorption of the Canine

Stafne and Austin (1945) made the claim that "any tooth that remains completely embedded, particularly over a long period, is liable to undergo resorption". Of 226 embedded teeth in which resorption occurred, 106 (47%) were maxillary canines. This is significant in that

although non-eruption of third molars exceeds that of maxillary canines, the incidence of resorption of canines is appreciably greater than that of third molars.

More recently, Azaz and Shteyer (1978) found 36 out of 252 palatal canines (14%) showed resorption. In most cases there was a local inflammatory factor such as non-vital adjacent teeth, periodontal involvement, or denture irritation. In five cases, no irritant factor was determined.

The most common site of origin of resorption is on the enamel surface, less often at the cemento-enamel junction, and rarely on the cementum. Blackwood (1958) showed histologically that resorption of enamel and dentine with subsequent invasion of vascular connective tissue may occur primarily through a defect in the enamel organ (reduced enamel epithelium). This epithelial covering protects the underlying enamel from invasion by the vascular mesodermal tissue of the follicle. Isolated defects in the enamel organ account for the irregular and fragmentary manner of resorption seen in these cases (Azaz and Shteyer, 1978; Shapira and Kuftinec, 1981).

Age seems to be a predisposing factor in resorption of palatal canines. Although found in young people, the incidence is highest in the later decades of life. Females are affected twice as often as

males, a finding Azaz and Shteyer (1978) cannot explain. This may simply reflect the higher incidence of palatally displaced canines in the female population (Section 3.2). Resorbed structures were found to be replaced by bone and this invasion of bone made subsequent removal of the canine difficult. If removal is indicated, then it should be done early, before resorption has a chance to firmly establish and ankylose the tooth (Stafne and Austin, 1945).

### 3.6.2 Resorption of Adjacent Teeth

Root resorption is found commonly throughout the population. Massler and Malone (1954) found radiographic evidence of root resorption in 86% of 13,263 permanent teeth. Every patient studied had at least one tooth with root resorption, an incidence much higher than previously reported. Their conclusion was that the permanent dentition possessed a definite resorptive potential.

Resorption of incisor roots adjacent to palatally displaced canines is seen occasionally (Fastlicht, 1954; Kettle, 1958; Feiglin, 1986). It is generally a painless process with the patient aware only of a gradual loosening of one or more incisor teeth. Sasakura et al (1984) found a 10:1 predominance of females with incisor root resorption but their sample is small and probably not significant (11 cases).

Brown and Matthews (1981) felt from their review of the literature that root resorption of adjacent teeth only occurs during the eruptive phase of the canine. However, they describe a case where onset of incisor root resorption was after 17 years of age when the eruptive phase of the canine should have been completed.

Where palatal displacement of the canine is suspected or known, the incisor roots should be monitored to prevent root resorption that may lead to premature loss of these teeth. The enigma remains that permanent teeth are rarely resorbed during normal eruption of adjacent teeth even though their crowns are in close contact with the roots of the erupted teeth.

## SECTION 4

### TREATMENT

A full discussion of treatment options of palatally displaced canine patients is beyond the scope of this manuscript and has been the subject of a previous thesis (Ratcliffe, 1977). Nevertheless, the essence of this work lies in a better understanding of the causes of canine displacement so that early detection and interceptive treatment of this condition may be facilitated and improved. This section will provide an overview of treatment options for the palatally displaced canine.

#### 4.1 INDICATIONS FOR TREATMENT

There are very few forms of palatal canine displacement that will not respond to treatment given reasonable cooperation from the patient. Nonetheless, it is not always desirable nor necessary to treat palatal canines. Provided there is no damage to the roots of the incisors, nor any cystic changes in the tooth follicle, little if any harm results from leaving an unerupted canine in the palate (Kettle, 1958). Sometimes it is best to remove the offending canine, but where the patient may benefit from definitive treatment to bring the canine into proper occlusion, this option should be exercised.

Definitive treatment will depend on the amount of space in the arch for the unerupted canine, the morphology and position of the adjacent teeth, resorption (if any) of the incisors, any cystic change in the tooth follicle, the position of the canine and ease of surgical access, the age of the patient, and importantly, the cooperation of the patient (Kettle, 1958; Moss, 1971; Hunter, 1983).

Horizontal canines generally show the poorest prognosis for treatment and positioning in the arch. Either no treatment, or surgical removal may be the best options. More oblique or vertical displacements need to be either removed or aligned as their retention may lead to resorption of incisors (Kettle, 1958). Where the choice is to remove or align, it is generally factors of age and cooperation that most influence the choice of treatment.

In younger persons, artificial eruption or surgical orthodontics should be considered before extraction of the palatal canine, simply because of its importance to the dentition in both esthetics and function. When eruption, even with orthodontic treatment, is not possible then surgical removal is indicated and should be done as early in life as possible (Baden, 1956; Thoma, 1963). Field and Ackerman (1935) felt that the vast majority of palatal canines should be removed unless orthodontics was used to align them. They also felt that some isolated cases definitely contra-indicated removal in the absence of clinical symptoms, but did not elaborate on this.

Baden (1956) and Thoma (1963) give the following as indications for removal of palatally displaced canines:

- (a) altered position of adjacent teeth;
- (b) root resorption of adjacent teeth;
- (c) caries;
- (d) neurological symptoms;

- (e) denture irritation (palatal canines are commonly overlooked in seemingly edentulous patients);
- (f) infection;
- (g) cysts and tumours; and
- (h) canines in unusual positions (badly displaced such as in the nose or antrum).

If removed, a decision must be made whether to replace the canine with a prosthesis or with a natural tooth via orthodontics. A retained deciduous canine can remain functionally useful for many years (frequently into the third decade of life) but may fail esthetically (Hartley, 1956). Prostheses often fail under functional loading. The first premolar can be orthodontically protracted into the canine space as a substitute (Altman, Arnold, and Spector, 1979) provided that a careful assessment is made of problems relating to unilateral mechanics and to tooth size discrepancies (Bishara et al, 1976). The height of the gingival margin on premolars is lower than that on canines, a factor that can be esthetically displeasing, especially with a short upper lip (Moss, 1971). Rayne (1969) believes, also, that the contact between the lateral incisor and first premolar is poor from a functional standpoint and would rather see a small self-cleansing space (small enough to please esthetically).

Where surgical access is hazardous to surrounding structures or where removal of the canine would result in much bone loss around the remaining teeth, it is often prudent to leave the canine in situ. Other contraindications to treatment are poor oral hygiene, high caries rate, unwillingness

to wear orthodontic appliances, some horizontal impactions, distally placed canine apex (near the first molar), and a recurved apex (Rayne, 1969; Di Salvo, 1971; Moss, 1971).

An attempt to bring the canine into occlusion can be made utilising the cooperation of the oral surgeon and orthodontist, or either specialist separately. Bell et al (1985) consider orthodontists are less likely to recommend surgical procedures than oral surgeons and vice versa, so that the choice of treatment may depend on which specialist sees the patient first.

## **4.2 SURGICAL TREATMENTS**

### **4.2.1 Exposure**

Surgical exposure of a tooth will only be successful if there is adequate space in the arch, the tooth is able to erupt, and the exposure can be maintained during eruption. The older the patient, the less the chance of the tooth fully erupting and frequently orthodontic therapy is required to properly align the canine (Moss, 1971). When the canine is more displaced palatally, exposure is necessarily followed by orthodontics to correct its occlusal position (see Section 4.3).

### **4.2.2 Surgical Transplantation**

The practice of heterogenous transplantation of teeth dates back to the early Greek, Roman, and Arabian physicians. Despite some short term "successes", the failure rate was, and still is, 100%. Following the work of

Widman at the turn of last century, success in autogenous transplantation increased. Holland (1955) described several cases of maxillary canine transplantation (with subsequent root canal therapy) and felt they were most successful when the root apex was open and the rotation less than  $90^{\circ}$ .

Moss (1968, 1971, 1975) also described a method of autogenous transplantation of palatally displaced canines aimed at delivering immediate alignment of the canine and decreasing treatment time considerably. He found that root canal therapy done at the time of the transplantation tended to make the reimplanted teeth more susceptible to resorption, and showed good results of transplantation without root canal therapy.

Whilst transplantation can be successful in any age group, adults are best suited for this procedure because they have ceased vertical growth of the alveolus, and often desire minimal treatment (Moss, 1971; Mulick, 1979).

#### 4.2.3 Surgical Repositioning

Where there is adequate space in the arch and the root apex is open and lying in the correct position, the canine can be surgically repositioned. This is done by rotating the canine around its apex without disturbing the neurovascular bundle in the hope that the still vital tooth will erupt into normal occlusion. Success depends on this procedure being

done at an early age, with an immature apex, and is only suitable in selected cases (Rayne, 1969; Moss, 1971; McKay, 1978).

#### 4.2.4 Surgical Alignment

McKay (1978) adopted this term to differentiate this procedure from transplantation or reimplantation procedures. Essentially the same, the major difference lies in that transplants are removed from the tissues during treatment, but in surgical alignment the tooth is positioned into a prepared socket and elongated to bring it into the occlusal plane without it leaving the tissues. A cast splint (used in transplantation) is not used, but rather a custom-made acrylic splint.

### 4.3 SURGICAL ORTHODONTICS

#### 4.3.1 Exposure and Eruption

"Experience has shown that this type of unerupted cuspid will erupt eventually without early orthodontic aid if given the opportunity to do so". This concluding remark made by James H. Keith (1945) typifies the conservative approach to treatment of palatally displaced canines, involving exposure and maintenance of the exposure by surgical pack, "and then just waiting for Mother Nature to do the rest - a great saving in time, expense, and inconvenience to the patient" (Lappin, 1951). It is still the procedure of choice by some oral surgeons (Norman, 1985).

Estimates of the time required for the exposed canine to erupt with the help of "Mother Nature" vary considerably:- Gwinn (1945) up to 18 months; Dewel (1949b) 4-6 months; Lappin (1951) 3-12 months; Helmore (1967) 6 months; Johnston (1969) 4-6 months; and Ohman and Ohman (1980) 1-24 months.

In order to facilitate eruption, Strock (1938) advocated channelling a trough through the bone through which the tooth may erupt, and cementation of a celluloid crownform filled with surgical dressing cream to maintain the exposure and guide eruption. Baden (1956), Reiser (1969), and Clark (1971) also followed this procedure.

Von der Heydt (1975) suggested packing gutta-percha into the follicular space between the labial surface of the crown and the socket in order to guide eruption of the canine away from the lateral incisor. This is a slight modification of the method used by George Bennett for patients of Charles Tweed where gutta-percha was packed into the follicular space on all sides of the crown (Gwinn, 1945).

A technique of exposure and light luxation ("stimulation") of the canine to encourage its eruption was described by Helmore and Norton (1954) and Helmore (1967). Clark (1971) also luxates the canine but only in the direction away from the standing incisors, a method endorsed by Altonen and Myllarniemi (1976). Clark (1971)

emphasises the delicacy of the luxation, describing it as a pivot around an axis of rotation located at the apex. Overzealous luxation may cause damage to the neurovascular bundle and loss of vitality. This in turn may stop eruption of the canine and possibly ankylosis if the periodontium becomes damaged (Godfrey, 1985).

#### 4.3.2 Exposure and Traction

Because it can take anywhere from one month to two years for "natural" eruption of the canine, then to be followed by a period of orthodontic therapy lasting twelve to twenty-four months, attachments have been placed on the canines at or around the time of surgery to facilitate eruption (via traction to orthodontic appliances) and decrease overall treatment time. Cementation of a pin into a prepared cavity in the exposed canine crown was suggested as early as Day (1894) and used by Kettle (1958) and Begg and Kesling (1977). Modification of this method of attachment by use of threaded pins obviated the need to cement in a wet field (Prescott and Goldberg, 1969; Porter and Rider, 1974).

Similar to this is cementation of a wire loop into a prepared cavity with amalgam or composite resin (Bishara et al, 1976; Fournier, Turcotte, and Bernard, 1982). Ligature wire threaded through a hole drilled through the cusp tip has also been described (Buchanan, 1967).

A non-invasive method was introduced by Bryant (1924). He constructed a gold cap to cover the canine crown tip and cemented it two weeks after exposure when the surgical pack was removed. Weiss, Jacobs, and Rafel (1953), Fastlicht (1954), Johnston (1969), Rayne (1969), and Lewis (1971) followed this method.

Taylor (1934) introduced a simple means of attachment by cementing brass wire to the exposed crown with black copper cement. Begg and Kesling (1977) also used this cement, but used stainless steel archwire material.

Stainless steel ligature secured around the cervix of the canine was first described by Lehman (1941). The ligature can be modified into a double lasso (Norton, 1971) and the ends fashioned into a hook, or a gold chain attached. Unfortunately, a large portion of bone overlying the crown must be removed and channelling is often required. This can lead to damage of the adjacent teeth (Shapira and Kuftinec, 1981). Furthermore, although stainless steel ligature is highly tissue compatible (Goldstein and Schpero, 1984), complications such as loss of gingival attachment, external resorption, and ankylosis can occur (Boyd, 1982).

A modification to the celluloid crownform method was made by Sly (1950) who included a thin sliver of band material to which a ring was attached into the crownform. This is cemented to the crown in the usual

manner. Where access is available, orthodontic bands have been cemented with hook, cleat, or ring attachments (Andreason, 1971; Bishara et al, 1976; Mulick, 1979).

The advent of polycarboxylate cements saw their use in cementing buttons or brackets welded to small pieces of band material (Schwartz, 1972; Stangl, 1976). They have been superceded by polyacrylate resins which bond well to etched enamel. These resins don't bond to stainless steel, however, and mechanical retention is necessary via wire gauze mesh to which can be attached 9 carat gold jeweller's chain or simply an orthodontic bracket (Nielson, Prydso, and Winkler, 1975; Reynolds and von Fraunhofer, 1976; Hunt, 1977; Levine and Skope, 1979; Mouser, 1980).

Advantages of bonded attachments lie in preselection of the most advantageous point of application for traction and the simplicity of the procedure. There is less extensive surgical removal of tissues for access than other methods, no trauma to adjacent teeth, no damage to the crown of the canine nor stripping of cervical attachment of the dental follicle leading to cemental resorption, reduced traction time, and little likelihood of failure (Mouser, 1980; Boyd, 1982).

## 4.4 ORTHODONTIC TREATMENTS

### 4.4.1 Palatal Pressure

According to Erikson (1938), the then late Dr. Hawley stimulated eruption of impacted canines via a vulcanite plate so constructed that occlusal forces would be distributed to the area overlying the impacted tooth. This constant stimulation, "in a large proportion of impacted teeth, cuspids particularly", caused eruption within a year or two.

Using this same concept of stimulating normal eruption, but utilising a different modality, Easthope (1982) constructed a removable appliance with an expansion screw angulated in the direction the canine is desired to be moved. Expanding the screw slowly (0.25 mm per week) applies gentle, constant pressure to the mucoperiosteum covering the unerupted canine stimulating its eruption towards its normal position. Age is not necessarily a factor but 11-16 years give the best results. Horizontal impactions, or those which lie with the crown near the apical third of the lateral incisor root (as viewed on an orthopantomograph) are contraindicated for this method.

### 4.4.2 Deciduous Canine Extraction

"I have never seen an impacted canine where serial extraction has been employed" (Johnston, 1969). The inference here is that early removal of deciduous canines may influence displaced canines to erupt

into correct position, although Mulick (1979) didn't believe this claim to have been systematically studied. Howard (1978) and Williams (1981) documented cases in which early removal of the deciduous canine had resulted in correction of the displaced permanent canine, and Lappin (1951) and Newcomb (1959) had previously advocated early removal of the deciduous canine when palatal displacement of the permanent successor was suspected. This would seem to contradict the theory of premature loss of the deciduous canine as an etiological factor (Section 3.5.1.3). Rayne (1969) recommended the removal of the deciduous lateral incisor and canine if the permanent lateral incisor was missing, and the removal of unerupted first premolars to relieve crowding and make conditions more favourable for canine eruption. This, of course, requires careful diagnosis at an early age.

#### 4.5 TIMING OF TREATMENT

The timing of any treatment regimen will vary according to the age at which the patient presents and the particular therapy chosen. Preventive measures (removing deciduous canines or enucleating first premolars) need to be performed early, around 8 or 9 years of age when a positive diagnosis of palatal canine displacement can be made (Newcomb, 1959; Williams, 1981). Surgical uncovering of canines should be timed as closely as possible to the normal physiological eruption time of the tooth (within two or three years) in order to utilise the patient's growth and maturation to advantage (Helmore, 1967; Altonen and Myllarniemi, 1976).

Palatal pressure appliances work best in early to middle teens (Easthope, 1982), and surgical manipulations are more suitable for adults (Moss, 1971).

#### 4.6 ANKYLOSIS

The problem of ankylosis occurs sporadically. Partial root resorption followed by repair with either cementum or bone can unite the tooth to the alveolar bone (Shafer, Hine, and Levy, 1974). In the case of the palatally displaced canine, ankylosis is difficult to diagnose radiographically due to the angulation of the canine and superimposition of maxillary structures. Where a minor inostosis has occurred at a defect in the periodontal membrane, luxation and immediate traction can be successful. True ankylosis, however, won't respond to traction and removal is recommended (Di Salvo, 1971; Vanarsdall and Corn, 1977; Mulick, 1979). If extraction of permanent teeth is being considered in the final treatment plan for a patient with palatal canine displacement, it is prudent to assure that the canine is not ankylosed and has a good prognosis before extracting (Bishara et al, 1976).

#### 4.7 RELAPSE PREVENTION

Treated palatally displaced canines are generally retained in a labial position by the positive interlocking occlusion. Many orthodontists, however, feel there is a tendency for these canines to relapse lingually, or to rerotate towards their original position. Clark (1971) eliminated lingual drift "by cutting a crescent, half-moon piece of tissue from the lingual aspect of the moved canine". This is similar to a partial pericision of gingival fibres except that tissue is removed

and the area is allowed to re-epithelialize. A full pericision technique may be warranted to help prevent rerotation as well as lingual drift, although the latter may occur less if more attention is given to buccal root torque of these orthodontically repositioned canines (Godfrey, 1986).

Zachrisson (1985) used either labial or palatal bonded retainers, sometimes in conjunction with removable retainers. The advantage of the bonded retainer is that it is simple, reliable, and neat, and allows more undisturbed soft tissue and bone healing over longer periods than can be obtained with removable retainers.

#### 4.8 PERIODONTAL CONDITION

There has been concern in the literature regarding the periodontal status of canines brought into position either from the buccal or palatal side of the arch. Atherton and Kerr (1968) studied changes in the gingiva during and after orthodontic movement and concluded that the changes were not permanent. Contrary to this, Becker, Kohavi, and Zilberman (1983) and Kohavi, Becker, and Zilberman (1984) found palatally displaced canines brought into position exhibited **permanent changes** in the periodontium. The 1983 study showed treated palatal canines to have a net further 4% bone loss compared with controls. In the 1984 paper, the authors concluded that radical exposure techniques caused more damage than minimal exposure techniques, regardless of the amount of force used in traction. They considered the cemento-enamel junction to be important in that exposure beyond this junction will cause loss of bone support. This concurs with Wisth, Nordervall, and Boe (1976a) who found moderate surgical exposure gave

the least periodontal damage. In another paper the same year (Wisth, Nordervall, and Boe, 1976b) they showed treated palatal canines to have significantly more loss of periodontal support on the buccal and palatal surfaces than did controls, and increased distal pocket depth, a finding corroborated by Smyth (1981).

Coatoam, Behrents, and Bissada (1981) considered 2.0 mm of keratinized gingiva comprising 1.0 mm of attached gingiva to be necessary to maintain gingival health. They found the width of keratinized gingiva could increase with orthodontic treatment unless there was none (0.0 mm) to begin with. Di Biase (1971) found no evidence to show that removal of palatal mucous membrane had any adverse effect on the height or condition of the gingival attachment following exposure, eruption, and alignment. This is contradicted by Heaney and Atherton (1976) who determined that exposure of unerupted teeth into unkeratinized alveolar mucosa resulted in periodontal pathology characterised by absence of attached gingiva and increased clinical crown length. This in turn can result in an increase in severity of chronic periodontal inflammation. They conclude that a flap procedure will minimize these problems, a recommendation endorsed by Smyth (1981).

## SECTION 5

### BIOMETRIC ANALYSIS OF THE DENTITION AND PALATE ASSOCIATED WITH THE PALATALLY DISPLACED MAXILLARY PERMANENT CANINE

#### 5.1 INTRODUCTION

There appear to have been no studies that have attempted an "in depth" biometric analysis of the dentition or palate in cases of palatal canine displacement. Only Bass (1967) and Brin, Becker, and Shalhav (1986) have assessed the Angle's malocclusion in these cases, other authors (Sections 3.2 and 3.4) confining themselves to more exoteric characteristics (incidence, side, sex, angular position, etc.).

Crowding of the maxillary arch has for so long been considered the major etiological factor in palatal canine displacement (Section 3.5.1.8), yet no one has attempted to verify (or deny) this biometrically. Jacoby (1983) tried "to establish the relationship between arch length and canine impaction" but failed to publish his methods and raw data, only presenting his results schematically.

Richardson and McKay (1983) related the inheritable nature of palatal canine displacement to an hereditary syndrome, but investigated no further. Palatal measures of height, width, and length have often been employed in the epidemiological assessment of craniofacial syndromes (Howell, 1981), but not as yet in cases of palatal canine displacement. This seems strange since the form of the palate is thought to be influenced to "a considerable extent" by the anteroposterior

relation of the mandible to the maxilla (Staab, 1962), an area already investigated (Bass, 1967; Brin, Becker, and Shalhav, 1986).

Vidic (1971) believed that the postnatal formation of the palate was more influenced by local development and functional forces (the action of the muscles of the tongue, of mastication, and of facial expression, as well as malocclusion, and respiratory dysfunction) rather than the result of the general formation of the craniofacial skeleton. It is also local factors that predominate in the list of etiological factors contributing to palatal canine displacement (Section 3.5.1).

The aim of this study was to assess some of these "local factors" by biometrically analysing the dentition and palate associated with the palatally displaced maxillary permanent canine in order to determine any morphological differences between affected and non-affected cases. Specifically, the biometric analysis was designed to evaluate observations made both in the clinic and from the literature which have raised the following issues:-

1. Studies overseas have found a higher incidence of palatal canine displacement in females, with the left maxillary canine tending to be displaced more frequently than the right maxillary canine (Section 3.2). What is the incidence of these traits (sex and position) in an affected Australian population sample?
2. Crowding of the maxillary arch is believed by most to be the major factor in palatal canine displacement (Section 3.5.1.8), yet this anomaly frequently appears in broad, spaced arches. Is crowding really a

factor and if so, to what extent (i.e. what is the measured value of spacing or crowding of the maxillary arch - could it be contributory to palatal canine displacement)?

3. Reduction in the mesiodistal width of the maxillary permanent lateral incisor crown and root has been shown to be associated with palatal canine displacement (Section 3.5.1.7). With reduction in the mesiodistal crown width of this tooth, is there also a reduction in the buccolingual crown width (i.e. an overall reduction in crown size)?
4. As much as the maxillary permanent lateral incisor root guides the eruption of the maxillary permanent canine, so too does the maxillary first premolar assist in determining the position of the canine. Where the canine has failed to erupt, the first premolar has not undergone its normal positional correction. A subjective clinical observation has been that these teeth tend to be rotated mesiolabially in conjunction with a palatally displaced canine. Whether this is cause or effect, or even incidental to the canine displacement is probably impossible to determine. Nevertheless, variability exists in the mesiodistal and buccolingual tip and the rotation of the first premolar adjacent to a palatally displaced canine, but is this any different to the first premolars in unaffected quadrants? In turn, how does this relate to the position of the normally erupted maxillary canine in

unilateral palatal canine displacement cases? Is this canine also lingually displaced and rotated or is it unaffected by the size and position of the approximal teeth?

5. Angle's molar classification has recently been recorded for a palatal canine displacement group in Israel (Brin, Becker, and Shalhav, 1986). How would this compare with an Australian population sample (affected group)? A corollary to the belief that crowding is a major factor in palatal canine displacement is the belief (albeit subjective) that these cases show hypoplastic maxillae and a tendency towards Class III malocclusions. Is this really so? Jacoby (1983) believed otherwise, that there was a tendency towards Class II, Division 2 type malocclusions in these cases. It is insufficient merely to look at the molar relationships to assess this factor. The incisor contact relationships must be assessed separately to distinguish the anterior and the posterior maxillo-mandibular dental relationship.

6. A further assessment of the relative incisor positions is the incisal overjet and overbite dimensions. If a small, crowded maxilla predisposed to palatal canine displacement, one would expect to find decreased overjet and overbite. On the other hand, Jacoby (1983) suggested one would find a deeper overbite. Is there a difference in the overjet and overbite associated with palatal canine displacement?

7. With hypoplastic maxillae, one would expect to find a tendency towards dental crossbite(s), particularly as one tooth already (the palatally displaced canine) has "crossed the arch". Is there a greater tendency towards crossbite associated with this anomaly?
8. A reduction in the mesiodistal width of the maxillary permanent lateral incisor would proportionally raise the overall Bolton's tooth-size ratio. Does this occur in cases of palatal canine displacement or is any reduction of the maxillary lateral incisor width offset by changes in widths of the remaining teeth (as suggested by Le Bot and Salmon, 1977)?
9. Given that palatal form is influenced by local factors, that the maxillary canine can be displaced into the palate, and that small, narrow arches supposedly predispose to palatal canine displacement, are there any real differences in palatal height, width, or length between affected and non-affected cases (i.e. do affected cases have relatively hypoplastic maxillae)?
10. The palate can be divided into a left and a right side by the median raphe overlying the midpalatal suture. Are palatal height and width dimensions equal (symmetric) on both sides or is there variation according to the side of palatal canine displacement? Does the median raphe run a straight course or is it deflected in affected cases, and is this reflected in the directions of the palatine rugae?

11. Palatal index and arch index have been used as a numerical means of conveying the relative form of the palate (Ashley-Montagu, 1934). How do these epidemiological indices relate to cases of palatal canine displacement?

## 5.2 MATERIALS AND METHODS

A sample group of cases showing palatal canine displacement was chosen from a computer record of patients referred to the University of Sydney Oral Surgery Department at the United Dental Hospital of Sydney between 1979 and 1986 for treatment (exposure or surgical removal) of unerupted maxillary permanent canines. Criteria for selection of the sample group included a positive diagnosis of unilateral or bilateral palatal canine displacement (verified at surgery), retained deciduous canine(s) in an otherwise permanent dentition (it was felt necessary to include only cases where the deciduous canine had not exfoliated nor had been otherwise lost in order that molar relationships could be correctly recorded, and that anatomical points of reference used for linear measurements would not be altered due to mesial drift of the buccal segments), and the availability of good plaster study casts without artefacts (air-bubbles) in the teeth or on the palatal surface.

A control group was selected from records of a twin sibling study made by A/Professor Godfrey in 1958. Criteria for selection were full eruption of the permanent dentition anterior to the second permanent molars, and presentation of good plaster study casts without artefacts (air-bubbles) in the teeth or on the palatal surface. Only one child from each sibling set was included, and none had undergone any orthodontic therapy.

The final selection consisted of a sample group containing 63 cases of palatal canine displacement and a control group containing 63 randomly selected unaffected ("normal") cases. The following records and measurements were taken:-

1. The age and sex of each case were recorded for both groups, and for the sample group, the position of the displaced canine (unilateral left, unilateral right, or bilateral) was also noted.
2. Crowding or spacing of the teeth was measured by the method devised by Seipel (1946) and advocated by Moorrees and Reed (1954), and was recorded separately for each arch. Where crowding was present, the mesiodistal crown diameter of each malaligned tooth was measured and compared with the amount of space available for it in the arch (Fig. 1). Spaces between teeth were measured using the modified (sharpened) tips of a Mitutoyo vernier caliper (Fig. 2) placed at the most distal point of the anterior tooth and the most mesial point of the posterior tooth. Spacing was denoted by a positive value, crowding by a negative value.

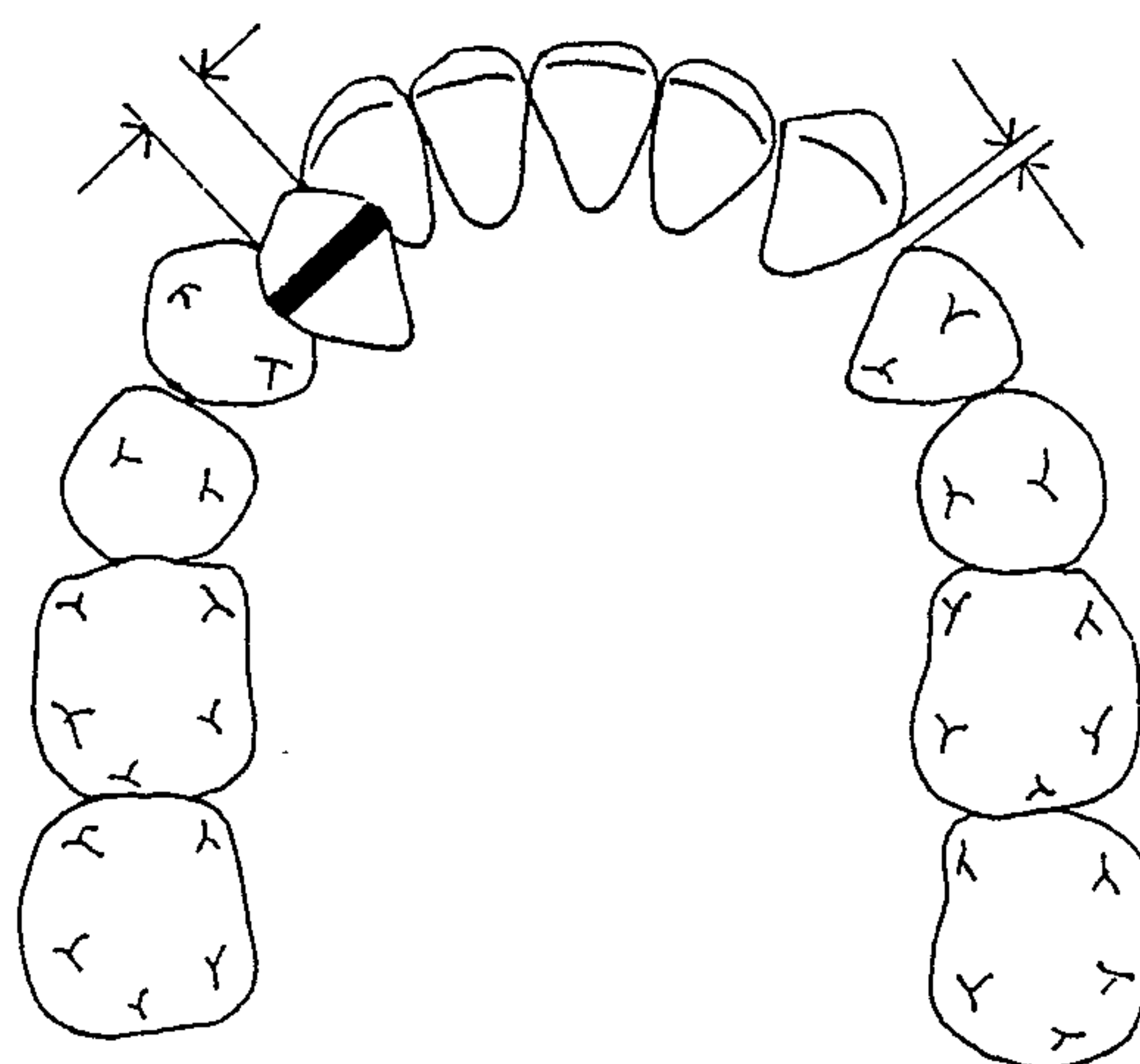


**Fig. 1**  
Measurement of spacing/crowding.

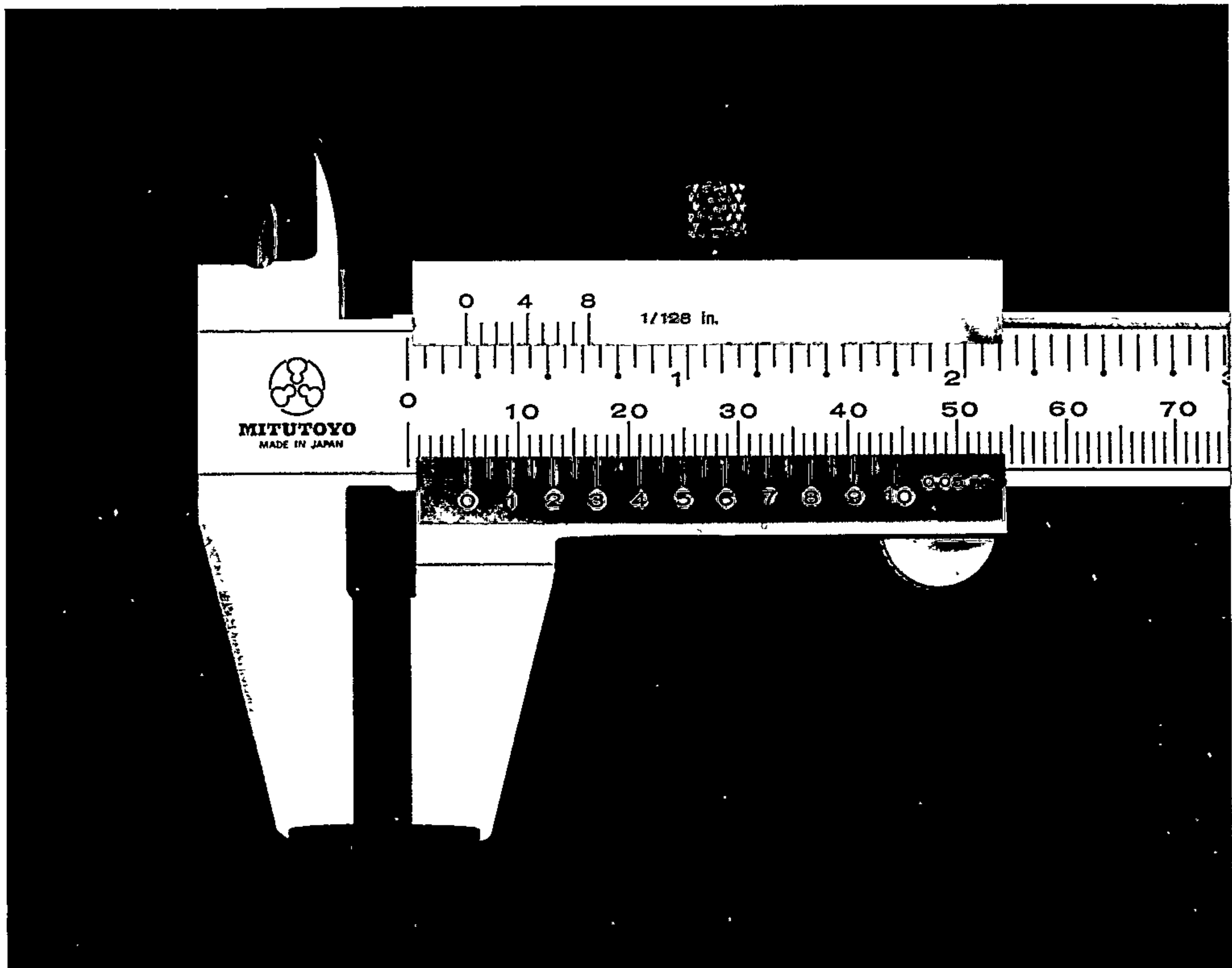


Fig. 2

Modified tips on Mitutoyo vernier caliper.

3. An assessment of the size (mesiodistal) of the maxillary permanent lateral incisors was made according to the criteria of Becker, Smith, and Behar (1981). These authors categorised the lateral incisor as normal, small (when the mesiodistal width was equal to or less than that of the matching mandibular permanent lateral incisor), peg-shaped, or absent. Becker and co-workers (1981, 1984) have commented on the association between lateral incisor crown shape and root size, concentrating their measurements on mesiodistal widths, the labiolingual dimension seemingly ignored. For this reason, the maximum labiolingual width of each lateral incisor was measured (to 0.1 mm) by orienting the vernier caliper beaks along the long axis of the crown, perpendicular to the incisal edge.

4. The situs of each maxillary first premolar was defined by recording the perceived position of the root apex (mesial or distal to the crown relative to an imaginary line perpendicular to the occlusal plane), the buccolingual cant of the crown (determined by placing a flat plane across the cusps of both first premolars and observing the relative cusp heights as advocated by Rayne, 1969), and the direction of any rotation present.

Similarly, for the normally erupted maxillary permanent canines of the control group and of the unilateral displacement cases in the sample group, the labiolingual position of these canines relative to the arch was recorded, as well as the direction of any rotation present.

5. Angle's molar classification and the incisor contact classification, as first described by Angle (1899), were recorded for both groups.
6. Overjet was measured using tangents to the labial surfaces of the maxillary and mandibular left permanent central incisors (perpendicular to the occlusal plane) and measured (to 0.5 mm) with the reverse end of the Mitutoyo vernier caliper (Fig. 3A). If rotation of one of these teeth was present, then the most anterior point on the crown was used. Class III incisors or lingual crossbite was recorded with a negative sign.

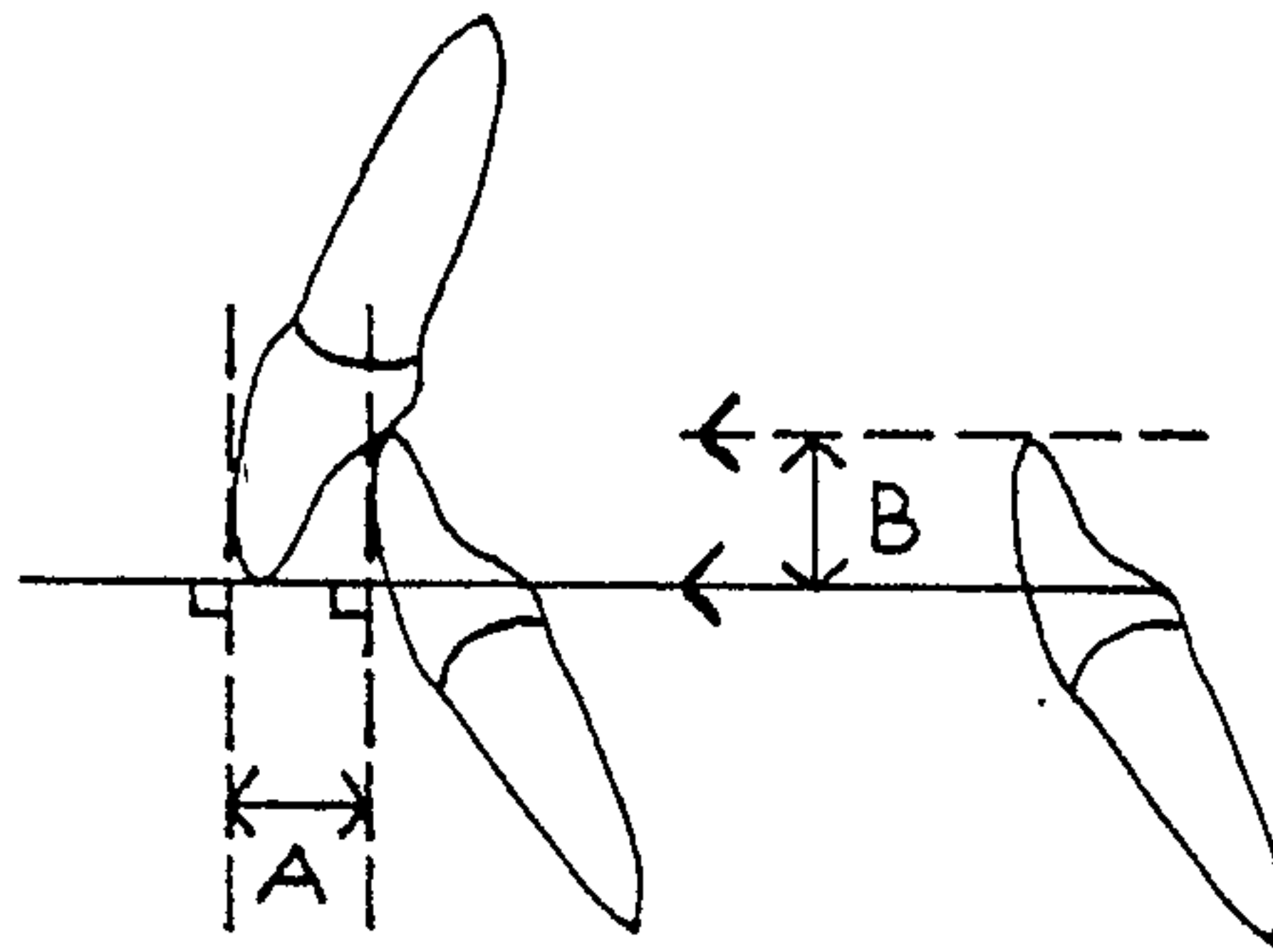


Fig. 3  
Measurement of (A) overjet,  
and (B) overbite.

Overbite was measured as the distance from the mandibular left central incisal edge to the point on its labial surface where the maxillary left central incisal edge is extrapolated along the occlusal plane when the casts are occluded in intercuspal position (Fig. 3B). This distance was also measured with the bar on the reverse end of the vernier caliper and was expressed both as an absolute distance (to 0.5 mm) and as a percentage of the clinical crown height of the mandibular left central incisor (measured from the incisal edge to the greatest depth of the gingival margin on the labial surface of the crown). This latter measurement was included as an alternative means of comparing mean overbite values (i.e. two groups may have identical mean absolute overbite values but may differ in mean percentage overbite values if one of the groups exhibits shorter mean crown heights - the amount of overbite will differ depending on the terms of reference used). Open bite was recorded with a negative sign.

7. Any crossbite(s) present in both the sample and control groups were recorded by noting the number of teeth involved and whether they were labial or lingual crossbites.
8. Bolton's ratio (Bolton, 1958, 1962) was calculated for the twelve maxillary and twelve mandibular teeth. Where the canine displacement was unilateral, the contralateral maxillary canine was measured twice to obtain the ratio. Where the canine displacement was bilateral, 1.0 mm was added to the mesiodistal width of each deciduous canine to allow for the average difference in width between these teeth and their unerupted successors as determined by Moorrees, Thomsen, Jensen, and Yen (1957).
9. Seven reference points were defined on the maxillary cast from which measurements of height, width, and length were taken (Fig. 4). The peripheral points were selected from the work of Sillman (1951, 1964) who observed arch dimension changes longitudinally in 65 subjects from birth to over 25 years of age. Sillman's points of reference were determined on the grounds of reproducibility through each series of dental casts used in his study and represent anatomical divisions.



**Fig. 4**

Reference points on maxillary cast.

The posterior peripheral reference points lie at the crest of the lingual aspect of the interdental papilla between the second premolar and the first permanent molar on each side of the arch. Palatal width and height are measured from this plane which corresponds to that used by Klami and Horowitz (1979) and Howell (1981).

The canine width (or more correctly, the width of the palate in the canine region) was measured from the crest of the lingual aspect of the interdental papilla between the permanent (or deciduous) canine and the first premolar on each side of the arch. No measure of palatal height was made from this plane as it was felt that the unerupted canines, which were lying at different levels within the maxillae, would render biased readings.

The most anterior reference point was located at the midpoint of the most anterior aspects of the permanent central incisors. Arch length was measured from this point perpendicular to the posterior reference plane.

Two points were located on the median raphe of the palatal mucosa coincident with the palatal width and canine width reference planes and were used to gauge symmetry along these planes (see later, point 10).

Palatal and canine widths were measured using the modified vernier caliper with sharp tips that allowed maximum access onto the plaster models. Palatal height was measured utilising a Vitrex profile gauge held perpendicular to the occlusal plane (Fig. 5). This provided a template of the palatal surface below the reference points which could then be transferred to a millimetre grid to read the maximum height (Fig. 6).

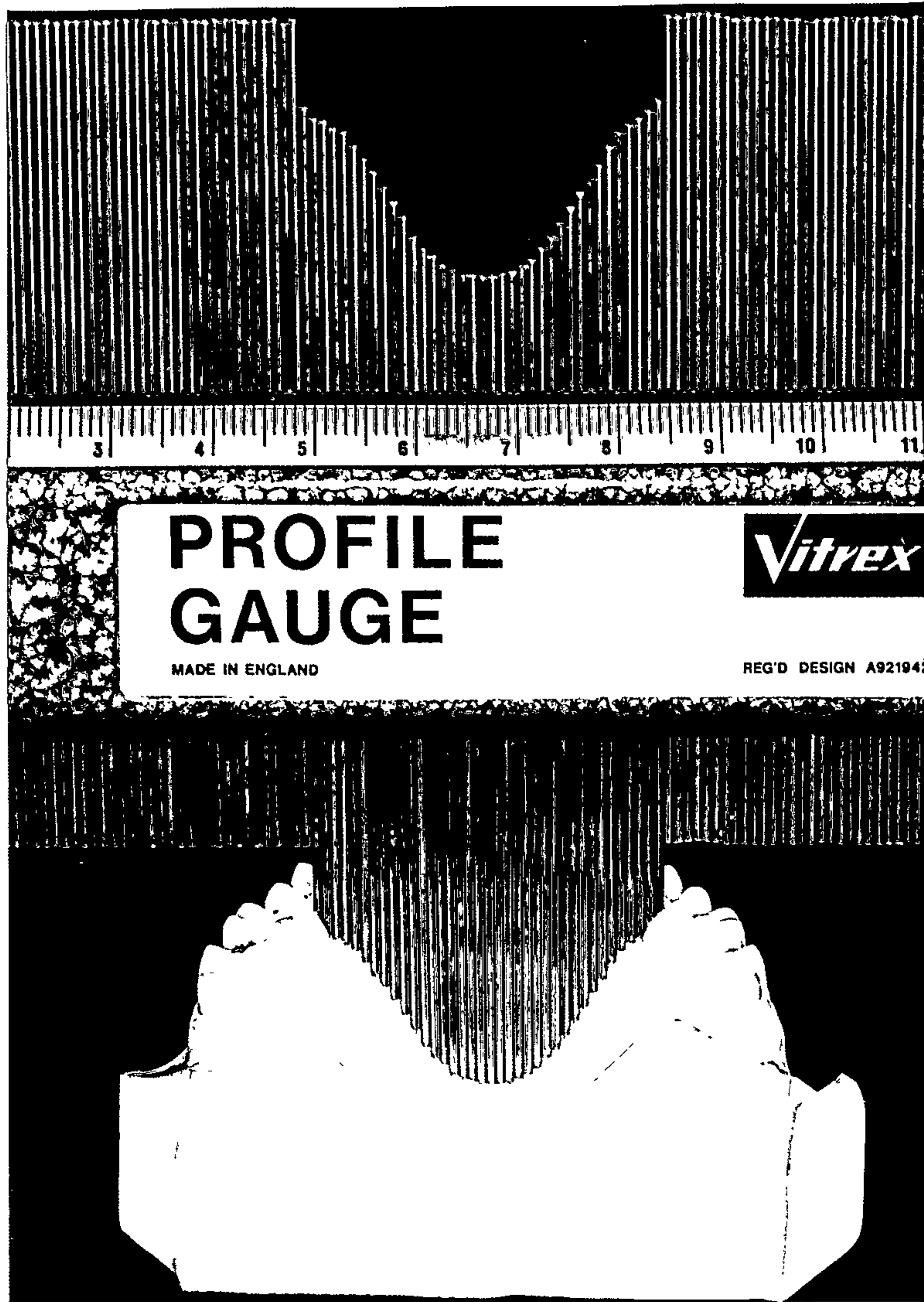


Fig. 5

Profile gauge in position on maxillary cast.

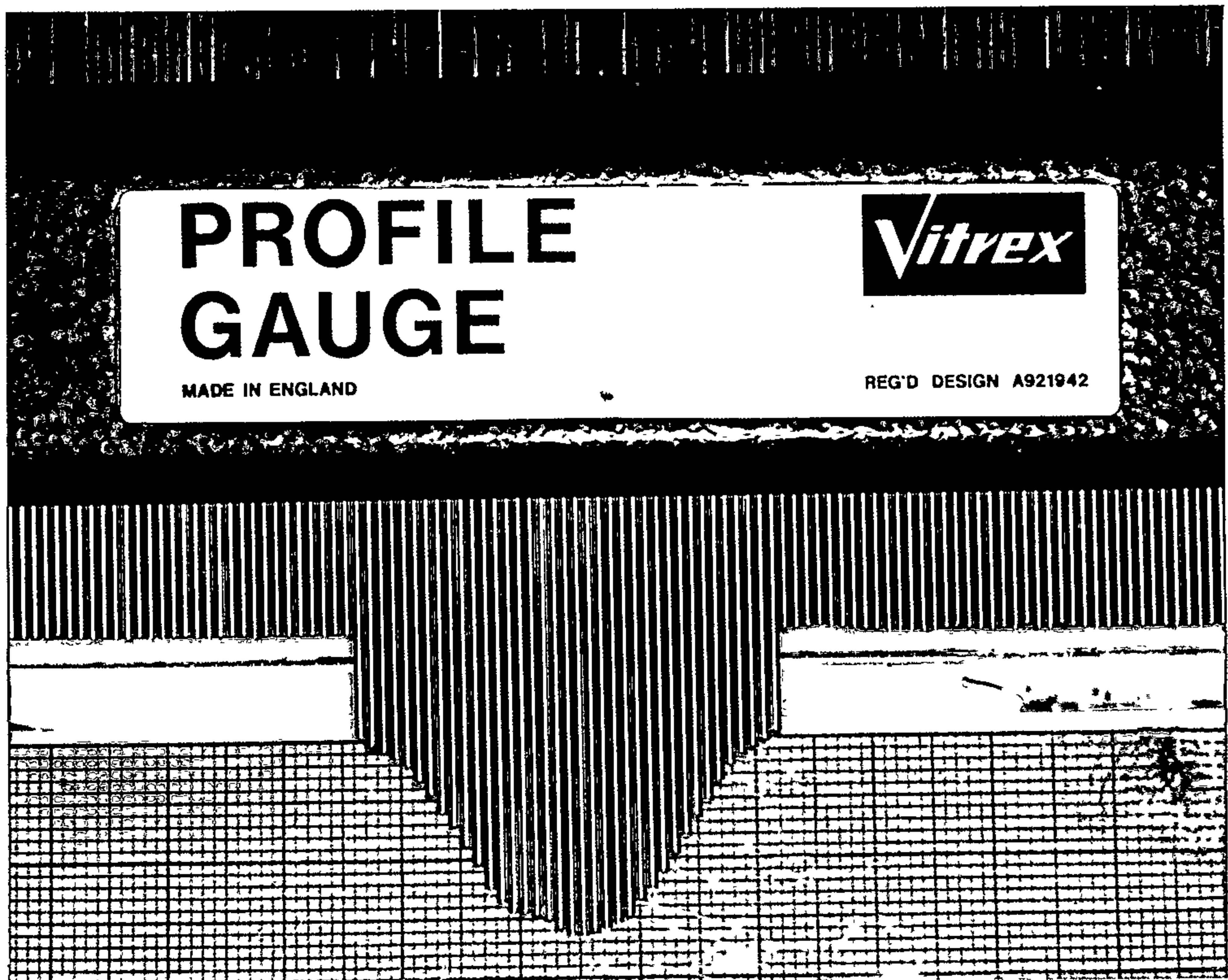


Fig. 6

Profile gauge on millimetre grid.

The profile gauge is the instrument used by both Klami and Horowitz (1979) and Howell (1981). It is a simple, inexpensive, and practical tool for measuring points on a curved surface, its only disadvantage lying in the relatively large width (1.0 mm) of each rod.

Arch length (already defined) was measured by placing the rigid plastic-encased millimetre grid across the maxillary teeth parallel to the occlusal plane with the posterior reference points along the base line. The length of the perpendicular line running to the interincisal point could then be read.

The smallest measurable unit in the palatal mensuration was limited by the millimetre grid which could only be read to 0.5 mm. Although the vernier caliper was accurate to 0.05 mm, it was decided to limit all palatal measurements to 0.5 mm for consistency of measurement, particularly as indices, correlations, and comparisons were to be made amongst these measures.

10. Symmetry of the palatal measurements either side of the median raphe was assessed by replacing the Vitrex profile gauge on the cast and raising the rod overlying the reference point on the median raphe (Fig. 4). The segment either side of the raised rod could then be measured to record differences in width (at the molar and canine reference planes) and height (at the molar plane).

Any obvious curvature or deflection from a straight line of the median raphe was recorded, and any asymmetry in the mean direction of the palatine rugae on each side of the palate (determined from the angle of intersection of the rugae with the median raphe) was noted.

11. Two indices were calculated, the palatal index

$$\left[ \frac{\text{palatal height}}{\text{palatal width}} \times \frac{100}{1} \right]$$

and the arch index

$$\left[ \frac{\text{arch length}}{\text{palatal width}} \times \frac{100}{1} \right].$$

These indices were in use at the turn of this century and were popularised by Ashley-Montagu (1934) as a numerical means of conveying the relative shape and form of the palate. More recently, they have been used for diagnostic purposes in craniofacial deformities (Shapiro, Redman, and Gorlin, 1963; Redman, Shapiro, and Gorlin, 1966; Gorlin, Pindborg, and Cohen, 1976), or for epidemiological purposes (Knott and Johnston, 1970; Howell, 1981).

All measurements were taken and recorded twice and the values averaged to reduce measurement error. A test of measurement reliability (or reproducibility) was made by randomly selecting 20 paired measurements of each variable and comparing the means of the first and second measures by Student's t-test. The results are presented in Table I and show good measurement reliability.

Each measured variable was then statistically analysed to show the range, mean, standard deviation, standard error of the mean, Snedecor's F-ratio, and Student's t-test (comparing the control group with the sample group). A  $\chi^2$  test was performed for the sex distribution and the positional (left/right) distribution to compare the observed frequencies with the expected frequencies, and correlation coefficients were calculated for the components of the palatal index and arch index in each group (Alder and Roessler, 1964; von Fraunhofer and Murray, 1974; Pipkin, 1984). In all, 26 variables were evaluated and recorded.

### 5.3 RESULTS

1. The sample group comprised 17 unilateral right side canine displacements (27%), 28 unilateral left side displacements (44%), and 18 bilateral displacements (29%). This gave a total of 81 displaced canines, 46 (57%) on the left and 35 (43%) on the right. The  $\chi^2$  test found no significant difference in this distribution.

The mean age of the sample group was  $15.6 \pm 3.0$  years (range 11-27 years) and contained 49 females and 14 males, a ratio of 3.5:1. This high distribution of females differed highly significantly

TABLE I

Test of measurement reliability.

| Variable              | First measure<br>n = 20 |                   | Second measure<br>n = 20 |                   | t    |
|-----------------------|-------------------------|-------------------|--------------------------|-------------------|------|
|                       | $\bar{x}_1$             | S.D. <sub>1</sub> | $\bar{x}_2$              | S.D. <sub>2</sub> |      |
| Spacing/crowding U/-  | 0.65                    | 2.66              | 0.70                     | 2.72              | 0.06 |
| Spacing/crowding -/L  | -0.07                   | 2.18              | -0.05                    | 2.18              | 0.03 |
| Labiolingual width 12 | 6.17                    | 0.63              | 6.15                     | 0.60              | 0.10 |
| Labiolingual width 22 | 6.15                    | 0.59              | 6.13                     | 0.56              | 0.13 |
| Overjet               | 3.27                    | 1.19              | 3.27                     | 1.08              | 0.00 |
| Overbite (mm)         | 3.65                    | 1.40              | 3.75                     | 1.46              | 0.21 |
| Overbite (%)          | 46.85                   | 18.47             | 48.50                    | 19.78             | 0.26 |
| Bolton's ratio        | 91.57                   | 2.11              | 91.42                    | 2.05              | 0.21 |
| Palatal height        | 15.40                   | 1.33              | 15.40                    | 1.47              | 0.00 |
| Palatal width         | 38.35                   | 1.80              | 38.22                    | 1.81              | 0.21 |
| Canine width          | 30.92                   | 1.85              | 30.77                    | 1.82              | 0.24 |
| Arch length           | 27.95                   | 2.09              | 27.90                    | 2.16              | 0.07 |
| Palatal index         | 40.21                   | 3.76              | 40.36                    | 4.26              | 0.11 |
| Arch index            | 73.04                   | 6.56              | 73.20                    | 6.61              | 0.07 |

(All t-test values are not significant  
indicating reliability of mensuration.)

( $p < 0.001$ ) from the expected binomial distribution according to the  $\chi^2$  test. Mean age of the control group was  $12.7 \pm 1.5$  years (range 10-16 years) and contained 36 females and 27 males, a ratio of 4:3 which is not significantly different.

2. The maxillary dental arch for both groups showed on average a small amount of spacing ( $< 1.00$  mm), the sample group having a slightly larger mean value by  $0.24$  mm (Table II). In contrast, the mandibular arches for both groups were slightly crowded on average ( $< 0.70$  mm) with the sample group again showing the greater mean value (a difference of  $0.50$  mm). These differences, however, were not significant for either arch.
3. Maxillary permanent lateral incisors showed a generalised reduction in mesiodistal width (Table III). Only 51% of the sample group were normal size compared to 72% of the control group. Small and peg-shaped teeth accounted for 46% of the sample group, but only 26% of the control, while absent lateral incisors were recorded in 3% of the sample group and in 2% of the control group. Buccolingual width was also reduced in the sample group ( $0.53$  mm mean difference on the left and  $0.56$  mm mean difference on the right). These differences were significant at  $p < 0.05$  (Table II).
4. Positions of the maxillary first premolars are shown in Table IV. No differences of position were found between the first

TABLE II  
Dental measures.

|                                               | CONTROL<br>(n = 63) |              |       |       | SAMPLE<br>(n = 63) |              |       |       |      |      |      |
|-----------------------------------------------|---------------------|--------------|-------|-------|--------------------|--------------|-------|-------|------|------|------|
|                                               | RANGE               | MEAN         | S.D.  | S.E.  | RANGE              | MEAN         | S.D.  | S.E.  | F    | t    |      |
| SPACING/CROWDING<br>(mm)                      | U/-                 | -4.0 - 11.0  | 0.74  | 2.71  | 0.34               | -9.0 - 7.0   | 0.98  | 3.21  | 0.40 | 1.40 | 0.46 |
|                                               | -/L                 | -5.0 - 5.0   | -0.17 | 1.89  | 0.24               | -8.0 - 8.0   | -0.67 | 2.82  | 0.36 | **   | 2.23 |
| LATERAL INCISOR<br>BUCCOLINGUAL WIDTH<br>(mm) | 12                  | 0.0 - 7.9    | 6.12  | 0.95  | 0.12               | 0.0 - 7.5    | 5.56  | 1.45  | 0.18 | **   | *    |
|                                               | 22                  | 0.0 - 7.9    | 6.09  | 0.97  | 0.12               | 0.0 - 7.5    | 5.56  | 1.29  | 0.16 | **   | *    |
| OVERJET (mm)                                  |                     | 1.5 - 7.0    | 3.68  | 1.31  | 0.17               | -1.5 - 11.0  | 3.15  | 2.21  | 0.28 | **   | 2.85 |
| OVERBITE                                      | (mm)                | 1.0 - 7.0    | 3.80  | 1.39  | 0.18               | 0.0 - 8.0    | 3.82  | 1.69  | 0.21 | 1.48 | 0.07 |
|                                               | (%)                 | 17.0 - 100.0 | 47.50 | 16.96 | 2.14               | 0.0 - 127.0  | 51.94 | 25.16 | 3.17 | **   | 2.20 |
| BOLTON'S RATIO (%)                            |                     | 86.3 - 109.0 | 91.98 | 2.96  | 0.37               | 87.0 - 101.8 | 93.04 | 2.95  | 0.37 | 1.01 | *    |

\* p<0.05  
\*\* p<0.01

**TABLE III**

Mesiodistal size of the maxillary  
permanent lateral incisors.

|        | CONTROL  | SAMPLE     |
|--------|----------|------------|
| Normal | 91 (72%) | 64 (51%) * |
| Small  | 33 (26%) | 45 (36%)   |
| Peg    | 0 (0%)   | 13 (10%)   |
| Absent | 2 (2%)   | 4 (3%)     |

\* The bilateral canine displacement group contained 7 lateral incisors that were borderline normal (<0.5 mm).

**TABLE IV**

Positions of the maxillary first premolars.

|                 | CONTROL  | SAMPLE   |
|-----------------|----------|----------|
| <b>Apex</b>     |          |          |
| mesial          | 13 (10%) | 28 (22%) |
| distal          | 23 (18%) | 47 (37%) |
| vertical        | 90 (72%) | 51 (41%) |
| <b>Crown</b>    |          |          |
| buccal          | 12 (10%) | 6 (5%)   |
| palatal         | 96 (76%) | 74 (59%) |
| vertical        | 18 (14%) | 46 (36%) |
| <b>Rotation</b> |          |          |
| mesiobuccal     | 63 (50%) | 57 (45%) |
| mesiopalatal    | 1 (1%)   | 4 (3%)   |
| nil             | 62 (49%) | 65 (52%) |

premolar on the affected and non-affected side. The control group showed predominantly vertical alignment (72%), the sample group much less so (41%). The remainder for both groups were tipped mesially (distal apex) twice as often as they were tipped distally (mesial apex). Crowns in the control group were mostly tipped palatally (76%), as were those in the sample group but to a lesser degree (59%), this group exhibiting more vertical crown positioning. Rotations occurred slightly more frequently in the control group and were mainly mesiobuccal (both groups).

Of the 126 erupted maxillary permanent canines in the control group, only 5 were positioned labially in relation to the dental arch, and none was positioned on the palatal side. 15 canines were rotated (12%), 8 mesiolabially and 7 mesio-palatally, but none showed a combination of aberrant position and rotation.

More variation was found in the 45 erupted canines in the sample group. 7 of these were lying labial to the arch and 6 were palatal. More particularly, rotations were present in 27 canines (60%), 10 mesiolabial and 17 mesiopalatal. 6 cases had a combination of aberrant position and rotation, each one being a palatal position with a mesiopalatal rotation (and 5 of these occurring on the right side).

5. Angle's molar classification (Table V) showed 1.5% less Class I and 6.4% less Class II relationships in the sample

**TABLE V**

Angle's molar classification.

|                           | CONTROL (n = 63) | SAMPLE (n = 63) |
|---------------------------|------------------|-----------------|
| Class I                   | 34 (53.9%)       | 33 (52.4%)      |
| Class II                  | 17 (27.0%)       | 15 (23.8%)      |
| Class II,<br>subdivision  | 9 (14.3%)        | 7 (11.1%)       |
| Class III                 | 0 (0.0%)         | 2 (3.2%)        |
| Class III,<br>subdivision | 3 (4.8%)         | 6 (9.5%)        |

**TABLE VI**

Incisor contact classification.

|                         | CONTROL (n = 63) | SAMPLE (n = 63) |
|-------------------------|------------------|-----------------|
| Class I                 | 46 (73.0%)       | 38 (60.3%)      |
| Class II,<br>Division 1 | 13 (20.6%)       | 9 (14.3%)       |
| Class II,<br>Division 2 | 4 (6.4%)         | 14 (22.2%)      |
| Class III               | 0 (0.0%)         | 2 (3.2%)        |

group. These differences accounted for the 7.9% increase in Class III relationships in this group. The incisor contact classification (Table VI) showed a decrease of Class I and Class II, Division 1 relationships in the sample group (12.7% and 6.3% respectively), a mild increase in Class III (3.2%) and a marked increase in Class II, Division 2 relationships (15.8%).

6. Mean overjet of the sample group was 0.53 mm less than that of the control group, not a significant difference (Table II). Mean overbite (mm) was almost identical for both groups (the sample group was 0.02 mm greater), but the mean percentage overbite value was 4.44% greater in the sample group (not a significant difference).
7. Crossbite was found in 10 cases among the control group, 5 lingual and 5 buccal. One of these was anterior, the other 9 posterior. With the exception of one case with a two-tooth segment crossbite, the remainder were single tooth instances, 4 on the left side and 6 on the right.

Contrastingly, the sample group contained 31 cases exhibiting crossbite, 6 buccal and 25 lingual. Of these, 9 were in the anterior region and 22 in the posterior region, with the left side affected twice as often as the right (21 cases versus 10 - in fact, the unilateral right canine displacements showed equal distribution left and right whereas the bilateral and unilateral left canine displacements

showed two and three times as many respectively left side crossbites than right side). 22 cases were single tooth crossbites and 9 cases contained multi-toothed segments in crossbite.

8. Bolton's ratio for the sample group (mean value) was 1.06% higher than that for the control group, a significant difference at  $p < 0.05$  (Table II).
9. Palatal measures are presented in Table VII. Palatal height was 0.29 mm greater in the sample group, whereas palatal width and canine width were 0.29 mm and 0.82 mm respectively smaller in the sample group. These differences were not significant. Only arch length, which was 0.79 mm smaller in the sample group, showed a significant difference ( $p < 0.05$ ).
10. Palatal height was generally greatest at the median raphe, but occasionally the raphe presented a broad and/or raised profile with greatest palatal height on one or both sides. Greatest palatal height in the control group was equally distributed between occurrence at or symmetrically about the median raphe and occurrence to one side of the raphe. This latter finding occurred equally on the right and on the left side. The sample group also showed an equal distribution of greatest palatal height at or equally either side of the raphe and on one side only of the raphe. The difference, however, was that when this occurred on one side only it did so overwhelmingly on the right side regardless of the

TABLE VII

Palatal measures.

|                     | CONTROL<br>(n = 63) |       |      |      | SAMPLE<br>(n = 63) |       |      |      |      |           |
|---------------------|---------------------|-------|------|------|--------------------|-------|------|------|------|-----------|
|                     | RANGE               | MEAN  | S.D. | S.E. | RANGE              | MEAN  | S.D. | S.E. | F    | t         |
| PALATAL HEIGHT (mm) | 11.5 - 19.5         | 15.16 | 1.49 | 0.19 | 11.5 - 19.5        | 15.45 | 1.71 | 0.22 | 1.32 | 1.00      |
| PALATAL WIDTH (mm)  | 31.0 - 42.0         | 38.07 | 2.06 | 0.26 | 31.5 - 45.0        | 37.78 | 2.79 | 0.35 | *    | 0.67      |
| CANINE WIDTH (mm)   | 26.5 - 36.5         | 31.12 | 1.96 | 0.25 | 24.5 - 38.5        | 30.30 | 2.72 | 0.34 | **   | 1.94      |
| ARCH LENGTH (mm)    | 24.0 - 33.5         | 28.75 | 2.02 | 0.25 | 23.0 - 33.0        | 27.96 | 2.27 | 0.29 | 1.26 | *<br>2.06 |
| $\frac{H}{W}$ (%)   | 28.1 - 59.7         | 39.96 | 4.69 | 0.59 | 31.3 - 54.5        | 41.14 | 5.41 | 0.68 | 1.33 | 1.31      |
| $\frac{L}{W}$ (%)   | 62.0 - 96.8         | 75.79 | 7.05 | 0.89 | 60.0 - 98.4        | 74.39 | 8.27 | 1.04 | 1.37 | 1.02      |

\* p<0.05

\*\* p<0.01

displacement category (i.e. the right side of the palate was slightly deeper or the left side more shallow, a significant difference from the expected result,  $p < 0.01$ ).

The palatal width measures of the control group were symmetrically extended either side of the median raphe reference point in only 25% of the cases. 75% were broader one side than the other, particularly the left side (41 cases versus only 6 cases where the right side was broader, a highly significant difference,  $p < 0.001$ ). Although the sample group had slightly more symmetric palatal width measures (29% of cases), the tendency towards a broader left side of the palate was not as marked (only 28 cases where the left side was broader and 17 cases where it was the right side - not a significant difference).

Symmetry of the canine width measures about the median raphe reference point was quite high for the control group (84%). The few remaining cases tended to be broader on the left side than on the right, but not significantly. In contrast, the sample group was much less symmetric (41% of cases) and when asymmetric (59% of cases) it was the right side that tended to be broader than the left, but not significantly.

The median raphe was deflected from its straight line course only once in the control group, that being to the left anteriorly. The sample group, however,

exhibited 20 cases (32%) with a deflected raphe, 18 to the left anteriorly (especially, but not exclusively, in unilateral left canine displacements) and 2 to the right anteriorly (both in unilateral right canine displacements).

The directions of the palatine rugae showed low symmetry values for both groups (control, 25%; sample, 19%) and when asymmetric were consistent in form with the rugae on the right side more posterolaterally angulated to the median raphe. No differences were observed between the two groups in this factor.

11. Calculations of palatal index and arch index have been presented in Table VII. A correlation coefficient ( $r$ ) was also calculated for each index in each group. For the palatal index, the correlation coefficient ( $r$ ) for the 63 paired palatal height and width values was 0.0 for the control group. The sample group correlation coefficient was 0.1. This means there was no linear correlation between paired values of palatal height and width in either group. Similarly, the arch index had a correlation coefficient ( $r$ ) for the 63 paired arch length and palatal width values in the control group of -0.1, and in the sample group, 0.1. Again, this means there was no linear correlation between paired values of arch length and palatal width in either group.

## 5.4 DISCUSSION

### 5.4.1 Position and Sex

The distribution of unilateral left and right, and of bilateral palatal canine displacements in the sample group was consistent with data presented in Section 3.2. The higher incidence overall of left side canine displacements (although not statistically significant) agreed with the non-Swedish studies cited, and the incidence of bilateral displacements (29%) is higher than the pooled average incidence of 19%, but still less than the 33% quoted by Nordenram and Stromberg (1966).

The 3.5:1 predominance of female cases was slightly higher than the grouped average of 2:1 in these cited studies, but falls well within the range.

### 5.4.2 Spacing/Crowding

The small average amount of spacing (1.00 mm) in the maxillary arches of the sample group confirms the statements by Richardson and McKay (1983) and Jacoby (1983) that crowding is not the single most important factor in palatal canine displacement. The control group also showed, on average, a small amount of spacing in the maxillary arches. The difference (0.24 mm) was not statistically significant, but the tendency towards greater spacing of the sample group maxillary arches than those of the control group cannot be ignored. It should be

remembered, however, that a criterion for selection of the sample group was the retention of the deciduous canine on the affected side of the arch to avoid the need to compensate for any secondary crowding that would occur from loss of proximal contact in the buccal segments. This coupled with the reduced size of the maxillary permanent lateral incisors may be the reasons underlying the slight amount of spacing observed. Nevertheless, crowding of the maxillary arch can no longer, on this evidence, be considered a major cause, nor even a general cause of palatal canine displacement.

The mandibular arches for both groups showed, on average, a slight amount of crowding. The sample group had a higher measure of crowding but this difference (0.5 mm) was not significant and may be the result of having a slightly older age group in the sample which would then tend towards increased anterior crowding from further mandibular growth (Enlow, 1982). This is corroborated by Moorrees and Reed (1954) who measured an average of 1.3 mm crowding in the mandibular dentitions of 72 females aged 18-20 years. These results would also appear to agree with Laine and Hausen (1985b) who found spacing equally distributed between the maxilla and mandible, but crowding more frequent in the mandible.

#### **5.4.3 Maxillary Permanent Lateral Incisors**

Only one half of the maxillary lateral incisors of the sample group were of

normal mesiodistal size, 46% being aberrant (small or peg-shaped). This finding was very similar to that reported by Becker, Smith, and Behar (1981), Chapman (1983), and Becker (1984). In contrast, the control group contained no peg-shaped lateral incisors but had 26% with reduced mesiodistal width, over six times the expected population frequency reported by Brin, Becker, and Shalhav (1986). These authors also reported a 93% expectancy of normal lateral incisors (in an Israeli community) whereas the control group in this study contained only 72% normal.

The mean buccolingual width of the lateral incisors in the sample group was significantly smaller than that in the control group ( $p < 0.05$ ). Moyers, van der Linden, Riolo, and McNamara Jr. (1976) have also measured the buccolingual width of this tooth and their mean value of 6.3 mm is not significantly larger than that of the control group (6.1 mm) but is significantly larger than that of the sample group (5.6 mm;  $p < 0.01$ ). This adds another aspect to the studies reported above that have measured the mesiodistal widths of lateral incisors, and to that of Becker, Zilberman, and Tsur (1984) who measured root lengths of lateral incisors adjacent to palatally displaced canines. Not only may a reduced mesiodistal crown width reflect a shortened, narrowed lateral incisor root, so may a reduction in buccolingual crown width have an associated narrowing of the root in this

same plane. This would further reduce the "target area" required by the permanent canine to guide its eruption.

#### 5.4.4 Maxillary First Premolars and Erupted Maxillary Permanent Canines

It was expected to find variation in the positions of the maxillary first premolars on the affected and non-affected sides of the sample group principally because this tooth had not undergone modification of its position (as described in Section 2.3.2) on the side of the palatally displaced canine. This expectation was not borne out. Instead of individual differences within the sample group, general differences were found between the control and sample groups. Where the control group showed a predominantly vertical alignment of the first premolar with a lingual crown tip (the position advocated by Andrews [1972] and Roth [1985] as functionally correct or desirable), the sample group showed an almost equal distribution of vertical and mesial crown (distal apex) alignment with less palatal and more vertical crown tip. Any rotations present (there were more in the control group than in the sample group) were almost invariably mesiobuccal, leading one to assume that this feature, although often seen in palatal canine displacement cases, is probably not contributory.

The erupted maxillary permanent canines of the sample group showed more variation in position than those of the control group.

This was manifest in the high number of rotations in the sample group, especially in conjunction with palatal position relative to the arch. It is unclear why the unilateral left canine displacement subgroup in particular contained most of the rotated and palatally positioned erupted canines. A simple explanation may be that these canines are less severe palatal displacements that have managed to erupt. It has also been a clinical observation (albeit an untested one) when observing exposures of palatally displaced canines that these teeth are rotated, but always mesiopalatally (see Sections 3.4.3, 3.5.1.2, 3.5.1.9).

#### **5.4.5 Angle's Molar Classification and Incisor Contact Classification**

The sample groups exhibited slightly less Class II molar relationships than did the control group, a finding in agreement with Bass (1967) and Brin, Becker, and Shalhav (1986). Converse to these studies, however, more Class III and less Class I molar relationships were found in the sample group than in the control group. Both groups differed in the distribution of molar relationships to other studies of malocclusion (Angle, 1899; Taylor, 1935; Massler and Frankel, 1951; Bass, 1967; Brin, Becker, and Shalhav, 1986) basically in that there were less Class I and more Class II molar relationships (Table VIII).

This is even more evident when one considers the different criteria used by Taylor (1935) and Massler and Frankel

**TABLE VIII**

Incidence of malocclusion (various authors).

|               | Angle<br>(1899) | Taylor<br>(1935) | Massler and<br>Frankel<br>(1951) | Bass<br>(1967) | Brin et al<br>(1986)<br>Canine Group | This Study |        |
|---------------|-----------------|------------------|----------------------------------|----------------|--------------------------------------|------------|--------|
|               |                 |                  |                                  |                |                                      | Control    | Sample |
| CLASS I (%)   | 69.2            | 76.7 (84.5)      | 63.5 (70.3)                      | 63.7           | 72.6                                 | 53.9       | 52.4   |
| CLASS II (%)  | 26.6            | 19.8 (13.2)      | 24.6 (20.0)                      | 29.3           | 20.5                                 | 41.3       | 34.9   |
| CLASS III (%) | 4.2             | 3.5 (2.3)        | 11.9 (9.7)                       | 7.0            | 6.8                                  | 4.8        | 12.7   |

For meaning of figures in brackets, see text.

(1951) who classified "normal" occlusion and "near normal" occlusion separately from Class I malocclusion. When these are grouped together as Class I molar relationships as was done in this study (figures in brackets in Table VIII), differences become more apparent. It should be remembered, however, that each study differs in its ethnic constitution - Angle studied White North Americans; Taylor, Australians of Anglosaxon descent; Massler and Frankel, White North Americans of Polish and Bulgar descent; Bass, an English population; Brin, Becker, and Shalhav, an Israeli population; and this study, Australians with mixed European heritage.

The incisor contact relationships showed more definitive differences (Table VI). The sample group showed a noticeable decrease in Class I and Class II, Division 1 relationships with a slight increase in Class III incisor relationships, and an especially large increase in the number of Class II, Division 2 incisor relationships. Bass (1967) also evaluated the incisor contact positions but included a category which he called "Class II indefinite" for cases that were neither typically Division 1 or 2, making his figures inappropriate for comparison.

The relatively higher frequency of Class II, Division 2 types found in the sample group may relate to suggestions made by Jacoby (1983) concerning the etiology of palatally displaced maxillary canines (see Section 3.5). The forward positioning of

the maxillary permanent incisor roots commensurate with this incisor tooth contact relationship may be reflected in decreased guidance of the permanent canine along the lateral incisor root during eruption, perhaps by simply providing excess space in the basal bone in which the canine can be "lost" (see Andrews, 1972, Fig. 8).

#### 5.4.6 Overjet and Overbite

The mean overjet of the sample group was less than that of the control group which is consistent with the increased number of Class II, Division 2 incisor contact relationships found in the sample group. The difference (0.53 mm) was not significant and both mean values compare favourably with figures for overjet produced by Moyers, van der Linden, Riolo, and McNamara Jr. (1976) whose mean value at 13.5 years of age is the same as that for the sample group.

Although the mean overbite (mm) was the same for the two groups, the sample group had a higher mean percentage overbite (4.44%). This difference in itself was not significant but reflects a shorter clinical crown height of the sample group mandibular incisors to the effect of 0.65 mm. Therefore, although the absolute overbite measures were the same, the sample group exhibited a deeper overbite by virtue of a deeper incisal overlap of a shorter mandibular incisor crown height. In comparison, Moyers, van der Linden, Riolo, and McNamara Jr. (1976) found

0.7 mm less overbite (absolute) than this study, but no percentage value for crown overlap was attainable.

#### 5.4.7 Crossbites

The greater variability of tooth position found in the sample group might be a reflection of the etiological factors involved in permanent canine displacement. The main feature of the crossbite distribution was the predisposition to lingual and left side loci, regardless of the side of canine displacement. Although mainly confined to single teeth, principally premolars and molars, the sample group contained many multi-toothed crossbites (including one bilateral canine displacement with a seven unit left side lingual crossbite).

#### 5.4.8 Bolton's Ratio

Given the high number of anomalous maxillary permanent lateral incisors (Table III) in the sample group, it was not surprising to find this group had a higher mean Bolton's ratio than the control group (significantly different,  $p < 0.05$ ), i.e. a relative deficiency of maxillary tooth structure. When compared to the Bolton Standard of  $91.3 \pm 1.91\%$  (Bolton, 1958, 1962), the mean difference was not significant for the control group (which had a higher ratio, again due to a relative frequency of mesiodistally reduced maxillary permanent lateral incisors), and was highly significant for the sample group ( $p < 0.001$ ).

Another contributory factor to this difference in the sample group (apart from the lateral incisor width) may be a decreased size of the maxillary permanent canines. While it wasn't recorded in this study, it has been demonstrated by other authors that agenesis or reduction of the maxillary permanent lateral incisor is associated with reduction in the crown measurements of all the other teeth, especially the permanent canines (Garn and Lewis, 1969; Baum and Cohen, 1971; Le Bot and Salmon, 1977).

#### 5.4.9 Palatal Measures

A wide variety of reference points has been reported for use in measuring palatal dimensions. Palatal width has often been measured from the lingual surfaces of the permanent first molars at the gingival margin (Brawley and Sedwick, 1939; Shapiro, Redman, and Gorlin, 1963; Redman, Shapiro, and Gorlin, 1966; Johnson and Baghdady, 1969; Scherra, 1969; Knott and Johnson, 1970). Some authors would specify the cervical point on the permanent first molars below the mesiopalatal cusp (Williams, 1964; Riquelme and Green, 1970), the most palatal point (Wisth, Thunold, and Boe, 1974; Laine and Hausen, 1985a), or the centroids (Moyers, van der Linden, Riolo, and McNamara Jr., 1976; Le Bot and Salmon, 1977).

These are all dental landmarks being used to measure a bony (palatal) distance.

They fail to take into account not only the great range of tooth morphology and size that can be encountered but also the variable positions that the first permanent molar may take within the alveolus (e.g. a unilateral lingual crossbite of only the first permanent molar will result in a narrower palatal width measure than may actually be present).

Palatal height measures are generally taken from the same reference points used for width measures. Here, again, a bony dimension is being measured from dental landmarks that may vary due to differences in tooth morphology and/or size.

Reference points used to measure arch length have also varied greatly, from Cole's use of the anterior nasal spine as the anterior point of reference in 1879 (Weinberger, 1918) to more common points such as the anterior aspect of the incisive papilla (Shapiro, Redman, and Gorlin, 1963; Redman, Shapiro, and Gorlin, 1966; Johnson and Baghdady, 1969; Knott and Johnson, 1970; Riquelme and Green, 1970) or simply the junction of the lingual surfaces of the permanent central incisors (Brawley and Sedwick, 1939; Williams, 1964; Le Bot and Salmon, 1977; Laine and Hausen, 1985a). Posterior points of reference for arch length have been the posterior nasal spine (Brawley and Sedwick, 1939; Shapiro, Redman, and Gorlin, 1963; Redman, Shapiro, and Gorlin, 1966), the line joining the most distal aspects of either the second

premolars, permanent first molars, or permanent second molars (Williams, 1964; Riquelme and Green, 1970; Moyers, van der Linden, Riolo, and McNamara Jr., 1976; Le Bot and Salmon, 1977), or the reference plane for palatal width (Johnson and Baghdady, 1969; Laine and Hausen, 1985a).

It would seem from this that arch length is an arbitrary measurement tailored to suit the purposes of the specific study in which it is used. It can represent palatal (bony) length as well as dental (anteroposterior arch) length.

Reference points used in this study for palatal mensuration were chosen for their ease of identification, reliability, and reproducibility. With the exception of the most anterior point (c.f. Fig. 4) they were non-dental (on thin soft tissue directly overlying bone) in order to minimise any deleterious effect caused by aberrant tooth morphology. The result of this was greater accuracy and reliability of measurement.

The mean palatal measures of the sample group tended to be smaller than those of the control group, with the exception of palatal height which was the reverse. Only arch length, however, showed any significant difference in mean value ( $p < 0.05$ ), a reflection of the lower frequency of Class II, Division 1 and the higher frequency of Class II, Division 2 incisal relationships in the sample group.

Control group palatal measures compared favourably with Sillman (1951) for palatal width, arch length, and canine width, and with Howell (1981) for palatal height, palatal width, and palatal index (see Section 5.4.11). Mean values for the control group tended to be slightly lower than the figures published by Sillman and Howell, which in turn indicates that the mean values for the sample group were even lower.

#### 5.4.10 Symmetries

Asymmetries have been reported as prevalent in Nature. Lundstrom (1961) reported many instances - right versus left-handedness (and corresponding leg preference), length of arm (the right arm is generally longer than the left), length of leg (the left leg tends to be longer than the right), mirror-image asymmetry in twins, and facial asymmetry (as exemplified by the classic sculpture, Venus of Milo). Moorrees and Reed (1964) reported asymmetries in crown diameters in human teeth, as have Garn, Cohen, and Geciauskas (1970) and Cohen, Garn, and Geciauskas (1970) studying the dentition associated with trisomy G (Down's syndrome).

Facial hemihypertrophy was illustrated by Rushton (1937, 1942), Rudolph and Norvold (1944), and Burke (1951) to more frequently affect the left side of the face, and unilateral cleft lip and palate has been shown to occur more frequently on the left side (Fogh-Anderson, 1961; see

Section 3.5.2.2). Graber (1978) has also drawn attention to the maxillary permanent lateral incisor which is more frequently congenitally absent on the left side than on the right.

With this in mind, it was not surprising to find such a high degree of asymmetry in the palatal measures for both control and sample groups. The only exception to this was the relatively high symmetry of the canine width measure in the control group.

The composite picture of the "typical" control group palate gained from the measurements is one with a straight median raphe placed a little to the right of centre in the molar region and ending centrally placed behind the central incisors. Greatest palatal height (in the second premolar/first molar region) is either at the raphe or equally on either side.

The composite picture of the "typical" sample group palate has a median raphe that is most often straight (70%) but in some cases curves to the left as it runs anteriorly (30%). It is situated slightly to the right of centre in the molar region and to the left of centre in the canine region, and greatest palatal height is either at the raphe or on the right side of it.

The sample group, specifically in the anterior region, tended to be broader on the right side of the raphe than on the left, perhaps reflecting the tendency for

the median raphe, if deflected, to do so towards the left side. It is unclear why the raphe is deflected as there is no break in the arch from missing teeth other than the palatally displaced canine (which may be left or right or both), and the deciduous canine is still present. A possible explanation has been given by Lundstrom (1961) who believed there was "convincing evidence of the presence of some systematic factor that induces a slight anterior shift of the left side of the maxilla as compared to the right side".

Part of this evidence was the asymmetric directions of the palatine rugae reported by Lysell (1955). Lysell found that the rugae on the right side of the raphe were directed more posterolaterally than the rugae on the left side, the same result as was found in this study. Lundstrom (1961) and Le Bret (1962) also found that the left side of the palate was broader than the right side at the first molar and first premolar level, but Hunter (1953) could find no significant differences between left and right palatal widths.

#### 5.4.11 Palatal Index and Arch Index

These indices proved to be a disappointment, not only because there was no significant difference between the mean values of each index for the control and sample groups, but also because there was no correlation ( $|r| \leq 0.1$ ) between palatal height and palatal width nor between arch length and palatal width.

The mean palatal index values found in this study are slightly higher than that reported by Redman, Shapiro, and Gorlin (1966) for juveniles, but slightly lower than the adult palatal index reported by Shapiro, Redman, and Gorlin (1963). This comparison should be made cautiously, however, as different reference points for mensuration were used (Section 5.4.9). Only Howell (1981), using the same method, has a comparable palatal index value which is marginally lower than the control group mean value.

Arch index values reported by Knott and Johnson (1970) are much higher than those found in this study. This means that either the arch length is greater and/or the palatal width smaller in the Iowa study, or the use of dissimilar reference points has invalidated the comparison.

Although the lack of correlation between the component parts of the palatal index and of the arch index has placed a dubious value on their usefulness in cross-sectional studies, it is possible that these indices are more suited to longitudinal studies such as that of Knott and Johnson (1970).

## 5.5 SUMMARY AND CONCLUSIONS

This biometric analysis of the dentition and palate associated with the palatally displaced maxillary permanent canine has produced the following conclusions:-

1. Palatal canine displacement tended to occur more frequently on the left side than on the right, and significantly more often in females than in males (3.5:1), a confirmation of the results of studies cited in Section 3.2.
2. Crowding of the maxillary arch was **not** an important factor in the etiology of palatal canine displacement. On average, there was a slight amount of spacing present in the maxillary arch, enough to accommodate the permanent canine.
3. There was an increased number of aberrant or missing maxillary permanent lateral incisors associated with palatally displaced canines. Concomitant with this was a general reduction in the buccolingual crown width of the lateral incisors present in affected individuals (significant at  $p < 0.05$ ).
4. Regardless of the side of canine displacement, the maxillary first premolars showed less vertical (mesiodistal) and less lingual crown tip. The large number of mesiobuccal rotations was no different (slightly less, in fact) than that found in individuals without canine displacement.

The majority of the erupted maxillary permanent canines were rotated, mainly mesiopalatally, and often in conjunction with a lingual position relative to the arch.

5. The maxillomandibular dental relationships showed a decrease in Angle's Class II and an increase in Angle's Class III molar relationships. There was a marked increase in Class II, Division 2 incisor contact relationships with a minimal increase in Class III and a decrease in Class I and Class II, Division 1 incisal relationships.
6. Overjet tended to be decreased and absolute overbite (mm) was no different to that of unaffected individuals. If expressed as the percentage overlap of the mandibular permanent central incisors, overbite was slightly increased reflecting a shorter clinical crown height of the mandibular central incisors of affected individuals.
7. There was an increased tendency towards lingual crossbite, especially on the left side, and regardless of the side of the canine displacement.
8. Bolton's ratio was increased (significant at  $p < 0.05$ ) reflecting a relative deficiency of maxillary tooth structure (primarily caused by the reduction in mesiodistal width of the maxillary permanent lateral incisors).
9. Palatal height was marginally increased while palatal width and canine width were slightly decreased. There was also a significant decrease in arch length ( $p < 0.05$ ). Together, these measures suggested a relatively hypoplastic maxilla. That this was relative rather

than absolute resulted from the differences between the sample and the control groups which were in part due to the larger number of females in the sample group. Sexual dimorphism has been shown to affect dental as well as palatal measures with females showing on average smaller dimensions than males (Moorrees, Thomsen, Jensen, and Yen, 1957; Moyers, van der Linden, Riolo, and McNamara Jr., 1976).

10. Palatal height tended to be greater on the right side of the median raphe than on the left. Palatal width tended to be broader on the left side, but this was reversed for the canine width which tended to be broader on the right side of the raphe. The side of the canine displacement appeared to have no effect on these findings.

There was an increased number of deflections of the median raphe, mainly to the left in the anterior region (regardless of the side of canine displacement). The palatine rugae showed no differences from unaffected individuals with the right side rugae more posterolaterally directed than those on the left side.

11. The palatal index value was higher reflecting a deeper but narrower palate. The decrease in the arch index value was attributable to the decreased arch length measure.

In relation to the etiology of palatal displacement of the maxillary permanent canine, the following local factors appear to be pre-eminent:-

- (a) slight spacing of the maxillary dentition (rather than crowding);
- (b) aberrant morphology of the maxillary permanent lateral incisor crown both mesiodistally and buccolingually; and
- (c) Class II, Division 2 type incisor contact relationships, especially in conjunction with Class I or even Class III molar relationships.

## 5.6 RECOMMENDATIONS

The aim of this study was to elucidate some of the local factors pertinent to the etiology of the palatally displaced maxillary permanent canine. Only through recognising these factors can secondary preventive measures aimed at guidance of eruption by interceptive orthodontics be instigated.

The range and interrelationship of etiological factors is broad and complex, and more study is necessarily required for clarification. Garn and Lewis (1969) and Garn, Lewis, and Vicinus (1963) have shown an association between agenesis of teeth and crown size reduction, and a relationship between agenesis of third molars and delayed development and eruption of the remaining teeth. A study of the relationship of agenesis and tooth crown size to the developmental timing of the maxillary permanent canine may prove useful, particularly as these factors are inheritable and affect the dentition as a whole.

Palatally displaced canines are usually rotated and the majority of erupted canines in the affected individuals in this study were also rotated. Is it possible that this rotation is contributory to, rather than a result of, palatal displacement? By being rotated mesiopalatally, the permanent canine may miss the "target area" of the permanent lateral incisor root and present its buccal crown surface rather than its mesial face for guidance. This different surface contour may misdirect the canine into the palate. The point to be investigated is whether the rotation is present before displacement, or as a result of it.

The most promising area of research, however, may probably lie in an investigation of the growth changes of the piriform aperture and the maxillary sinuses which are closely related to the developmental sites of the permanent canines (see Sections 3.5.2.2 and 3.5.3). This study has found a slight maxillary hypoplasia associated with palatal canine displacement. Whether this is reflected in nasal orifice and maxillary sinus development could prove interesting in that it may relate nasal respiration to growth of the maxilla and the development of its dentition.

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## SECTION 6

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## SECTION 7

## APPENDIX

Statistical methods:

$$\text{For } n > 30, t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$$= \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\text{SE}[\bar{x}_1])^2 + (\text{SE}[\bar{x}_2])^2}}$$

$$\text{SD}(S) = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

$$\text{SE} = \frac{S}{\sqrt{n}}$$

$$F = \frac{s_1^2}{s_2^2}$$

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\left[ \sum (x - \bar{x})^2 \cdot \sum (y - \bar{y})^2 \right]}}$$

$$\text{for which } t = \frac{r \sqrt{n - 2}}{\sqrt{(1 - r^2)}}$$

$$\text{Chi}^2 (\chi^2) = \sum \left[ \frac{(O - E)^2}{E} \right]$$