SURGICAL MANAGEMENT OF IMPACTED MAXILLARY CANINES USING THE ACID-ETCH BONDING TECHNIQUE

M.D.Sc. THESIS

1992

UNIVERSITY OF SYDNEY

Peter G. Mouser

DENTISTRY LIBRARY
UNIVERSITY OF SYDNEY

CONTENTS

CHAPTER 1 - INTRODUCTION

CHAPTER 2 - LITERATURE REVIEW

2.1. NORMAL DEVELOPMENT AND ERUPTION

2.2. DEFINITIONS OF IMPACTION

2.3. AETIOLOGY OF IMPACTION

2.3.1 PRIMARY CAUSES

(i) Early development position
(ii) Deflection during eruption

a. Retained Deciduous Canines
b. Permanent Lateral Incisors

(iii) Space loss in the dental area
(iv) Obstruction

a. Supernumerary Teeth
b. Dentigerous cyst, dental follicle, alveolar soft tissues
c. Odontoma

(v) Cleft palates
(vi) Ankylosis

2.3.2 SECONDARY (SYSTEMIC) CAUSES

(i) Hereditary disorders
(ii) Endocrine disorders
(iii) Vitamin D deficiency

2.4 STATISTICS

2.4.1 INCIDENCE OF IMPACTED MAXILLARY CANINES

2.4.2 SEX DISTRIBUTION

2.4.3 UNILATERAL OR BILATERAL IMPACTIONS

2.4.4 SITE OF IMPACTION IN THE ARCH

2.4.5 RETAINED DECIDUOUS CANINES

2.4.6 PERMANENT LATERAL INCISORS

(i) Absence, peg-shaped or small
(ii) Resorption by impacted canine

2.4.7 SUPERNUMERARY TEETH, ODONTOMA AND FOLLICULAR ENLARGEMENT

2.4.8 AGE DISTRIBUTION

2.5 ASSESSMENT OF IMPACTED MAXILLARY CANINES

2.5.1 CLINICAL ASSESSMENT

2.5.2 RADIOGRAPHIC ASSESSMENT

(i) Parallax localization
(ii) Stereoscopy
(iii) Panography
(iv) Localization by views taken at contrasting angles
(v) Radiation dosage

2.6 CLASSIFICATION OF IMPACTED MAXILLARY CANINES

2.7 SURGICAL TECHNIQUES FOR MANAGEMENT OF IMPACTED MAXILLARY CANINES

2.7.1 LEAVE IN SITU

2.7.2 SURGICAL REMOVAL

2.7.3 TRANSPLANTATION

2.7.4 SURGICAL EXPOSURE OF THE IMPACTED CANINE

(i) Theoretical Considerations
(ii) Surgical Techniques

2.7.5 ATTACHMENT FOR ORTHODONTIC TRACTION

(i) Cementation of crowns and bands
(ii) Ligation with wire

CHAPTER ONE

INTRODUCTION

Effective management of impacted maxillary canines remains a challenging task for orthodontists and oral surgeons. As Howard stated in 1970, the variety of methods described in the literature is a measure of the ingenuity that has been exercised in the treatment of this problem and suggests that the ideal method of treatment may not yet have been found. The positioning of the impacted canine into the dental arch taxes the skill of the orthodontist and surgeon alike, and without co-operation between them this key tooth will not be allowed to play its unique aesthetic and functional role.

The purpose of this treatise is to review the literature on the techniques of gaining attachment to the impacted maxillary canine, and then to assess the acid-etch bonding technique as developed in the Department of Oral Medicine and Oral Surgery, University of Sydney.

CHAPTER TWO

LITERATURE REVIEW

2.1 NORMAL DEVELOPMENT AND ERUPTION OF THE MAXILLARY PERMANENT CANINE.

The development and eruption of the permanent maxillary canine has been described and discussed by many reputable authors (Broadbent, 1941; Dewel, 1949; Fastlicht, 1954). A recent paper by Hunter (1981) presents the currently accepted concept of the development of the tooth and is summarised as follows.

The crown begins calcification at four to five months of age, and at one year is found lying high in the maxilla above the bifurcation of the first deciduous molar roots, immediately below the floor of the orbit. From this position to the occlusal plane the path of eruption is more tortuous and unpredictable than for any other tooth. As the deciduous teeth erupt, the permanent incisor and canine crypts migrate rapidly forward in the maxilla, until by the age of three years the permanent canine lies just above the apex of the deciduous canine, the crown directed mesially and somewhat palatally. While growth of the face continues and carries the deciduous dentition downwards and forwards, the permanent canine remains relatively high in the maxilla, its root development only beginning at the age of seven years. As the root begins to form the canine moves toward the occlusal plane, the crown lying in close proximity to the root of the erupted, permanent lateral incisor. It then passes down the distal aspect of this incisor root emerging into the mouth at eleven to twelve years of age. Because the canine impinges on the distal surface of the lateral incisor root during its eruption the crown of the incisor becomes distally inclined, taking on the typical splayed

appearance. By twelve years the canine has usually reached the occlusal plane and the lateral incisors become more mesially inclined, closing the remaining spaces.

Williams (1981) considered the positional changes between eight and ten years of age as needing especially careful observation. During this stage of development the canine seems to migrate buccally from a position palatal to the apex of its deciduous precursor, and then continue its long intrabony descent as the deciduous canine root resorbs. It is during this extended and complicated path to eruption that a deflection or blocking may occur, with resultant displacement and impaction.

Deviations may occur from the ideal path of eruption. The canine may be displaced labially if a deficiency of space available in the arch arises during its eruption and emergence into the mouth. Deflection of the canine crown to the palatal aspect of the lateral incisor root will allow the canine to move to a position medial to the apex of the lateral incisor, and on towards the maxillary midline.

2.2 DEFINITION OF IMPACTION

The term impacted has various meanings to people who attempt to define it. The common threads in all the definitions are:-

a. Delayed eruption beyond that normally expected in a particular individual (Aitasolo, Lehtinen and Oksala, 1972; Gensior and Straus, 1974; Ohman and Ohman, 1980).

b. When contact with an adjacent object, such as tooth or bone, acts as a physical barrier to the eruption of the tooth. (Adamson, 1950; Blum, 1923; Hitchin, 1956; Mayers, 1975; Shafer, Hine and Levy, 1974).

Probably the best definition is that of Archer (1975) and is the one applied throughout this treatise. He defined impaction as "a tooth which is completely or partially unerupted, and is positioned against another tooth, bone or soft tissue so that its further eruption is unlikely, described according to its anatomic position".

In using this definition which may be applied to any tooth, I have avoided the confusion that surrounds the use of the term "unerupted" as proposed by Van de Heyt (1975) and Jacoby (1983) in describing canines displaced to the labial of the arch even though this tooth may remain "unerupted" many years past the expected age of its emergence. They still accept the term impacted for canines placed either within the dental arch or on the palatal aspect of it. Using Archer's definition the tooth is "impacted" regardless of its relation to the dental arch.

2.3 AETIOLOGY OF IMPACTION OF THE PERMANENT MAXILLARY CANINE TOOTH.

The long and relatively tortuous path of eruption of the canine is given as the reason for its high rate of impaction by all who discuss the subject. As has been described, the canine begins development before its immediate neighbours, yet does not erupt till long after they have taken their place in the dental arch. This lengthy period provides every opportunity for disruption of the development, or deviation in the path of eruption which may lead to the

tooth becoming impacted. The many proposed causes for this disruption are listed as follows.

2.3.1 PRIMARY (LOCAL) CAUSES

i. Early developmental position

ii. Deflection during eruption

   a. retained deciduous canine

   b. lateral incisors

iii. Space loss in the dental arch

iv. Obstruction

   a. supernumerary teeth

   b. dentigerous cyst, soft tissues

   c. odontoma

v. Cleft palate

vi. Ankylosis

2.3.2 SECONDARY (SYSTEMIC) CAUSES

i. Hereditary disorders

ii. Endocrine disorders

iii. Vitamin D deficiency

There has been substantial discussion in the literature of each of these causes as summarised below under the appropriate headings.

2.3.1 PRIMARY (LOCAL) CAUSES

i. Early developmental position

The early development of the canine in the correct anatomical position is dependent on the normal growth of the maxilla permitting space for it to progress from the region of the first deciduous molar to its position above the root apex of the deciduous canine, (Moss 1971), and then, as the individual grows, along the normal path to the mouth. Williams (1981) noted that between the ages of eight and ten years the canine seems to migrate buccally from its position just palatal to the apex of the deciduous canine, initiating the latter's resorption and beginning its descent into the mouth. He made the point that careful assessment of the canine position during this period is required to be certain of its buccal migration to the correct position for eruption. The continued presence of the canine on the palatal aspect was explained by Jacoby (1983) as being due to extra space being available in the maxilla allowing the canine to "dive" within the bone and become palatally impacted as it begins its eruption.

Thilander and Jacobsson (1968) assessed the importance of developmental position in a longitudinal study of 384 children. They found that canine teeth that were palatally situated at approximately 11.5 years showed little tendency to erupt normally, with the majority still unerupted at the second examination at 17.8 years. They concluded that a palatal direction of eruption was one of the most important local factors responsible for impaction, and stressed the importance for assessment at an early age (preferably eleven years) in

order to be able to commence suitable treatment without delay in cases where impaction is predicted.

ii. Deflection during eruption

A consistent finding in patients with impacted canines is the retention of the deciduous canine usually with relatively complete root formation. In patients with impacted canines, another consistent observation is that the permanent lateral incisors are either small and peg-shaped or congenitally absent. The roles these two findings play in the aetiology of impaction is unclear; however, the assumption that their presence is the cause of the impaction has been made by many authors.

a. Retained deciduous canines

Graber (1972) stated that if the roots of the deciduous teeth are not resorbed properly, uniformly or on schedule, the permanent successors may be either withheld from eruption at a time when the corresponding teeth are erupting in other segments, or they may be deflected into malposition. Other authors (Fastlicht, 1954; Hitchin, 1956; Kettle 1957-1958) felt that the presence of apical pathosis on the deciduous canine was necessary to prevent the continued eruption of the permanent canine. More recently the opposing view has been presented; that is, the deciduous canine is retained because the permanent canine has moved away from the deciduous root thus no longer causing it to be resorbed, and thus the retained deciduous tooth is a symptom of the impaction not a cause. (Johnson, 1969; Moss 1971; Thilander and Jakobsson,

1968). This throws some doubt on the suggestion that the deciduous lateral incisor somehow acted as a guide for the canine in its eruption, (Dewel, 1949; Johnson, 1969). In an attempt to resolve this point Graber (1972) altered his emphasis, and stated "The subject of prolonged tooth retention versus abnormal eruption has "chicken and egg" overtones. Which came first? Which is primary? Is the permanent successor being deflected by the abnormal resorption, or is there abnormal resorption of the deciduous tooth because of the abnormal path of eruption of the permanent tooth? It is not always possible to make a firm differential diagnosis. The important thing is to recognise the departure from normal."

b. Permanent lateral incisors

The lateral incisor acts as a guide for the erupting canine in its path to the mouth by providing its distal surface to deflect the mesially drifting canine to a more vertical position, (Hunter, 1981; Jacoby, 1983). The presence of a normally shaped tooth, in its normal position, would therefore appear essential for the canine to emerge in the correct position (Moss, 1971)

Kettle (1957-1958) included congenital absence of lateral incisors in the aetiology of canine impaction, as their absence allowed sufficient mesial drift of the canine for it to come into contact with the incisor, or to pass its normal position and become displaced palatally. Miller (1963-1964), surveyed 50 patients and concluded the mesial deflection or delayed eruption of canines may occur in patients with missing lateral incisors, small arches, or

early loss of the deciduous lateral incisor with mesial drift of the buccal segment. Miller also felt that the roots of peg-shaped lateral incisors were usually of adequate length to guide the canine in its normal course.

By far the most comprehensive study is that of Becker, Smith and Behar (1981), who looked at the incidence of anomalous maxillary lateral incisors in relation to palatally displaced canines. They stated that there appear to be two processes in the palatal displacement of the maxillary canine. The first is a developmental one related to the absence of guidance by the lateral incisor which allows a new course for a downward path of the canine on the palatal side of the alveolus. The second relates to a later period when the canine is moving down into a narrower part of the alveolus. If given the space, or only the interference of deciduous teeth, it will tend to improve its position and frequently break through the mucosa on the buccal or labial side. The presence of permanent tooth roots at this later stage can prevent the rectifying movement of the canine. Becker (1984) noted that small teeth develop late, thus explaining that the late developing lateral incisor, (calcification beginning at 10 to 12 months) which may be even later if it is small or peg shaped, may be insufficiently developed to afford the critical guidance at the very early stages of development and movement of the canine. Once the canine has moved to the palatal aspect of the alveolus the late developing root of the small or peg shaped lateral incisor blocks the "corrective" buccal migration of the canine. This would account for the high incidence of peg- shaped (17.2%) and otherwise small (25%) lateral incisors that were found adjacent to

palatally displaced canines, and the relative infrequency (5.5%) of congenital absence reported by Becker, Smith and Behar (1981).

Becker (1984) stated "There is a definite link between reduced crown-size of lateral incisors and a shortening of their roots. There is also a definite link between shortening of the roots of the lateral incisors adjacent to palatally impacted canines."

iii. Space loss in the dental arch

Loss of space in the canine region due to early loss of the deciduous teeth, particularly the deciduous first molar, has been blamed for canine impaction, as the space normally available for it is taken by the mesial drift of the first premolar (Fashlicht, 1954; Kettle, 1957-1958; and Van de Heyt, 1975). Dewel (1949) recognised that many cases of palatally impacted canines had normal, uncrowded occlusions with sufficient, or almost sufficient, space to accommodate the canine in its normal position, thus questioning crowding as the aetiology of impaction.

The comparison between buccal and palatal impaction of canines shows different aetiologies, with buccally displaced or impacted canines occurring much more frequently in crowded mouths. (Thilander and Jakobsson 1968). Severe crowding leads to a loss of space for the canine, forcing it to take a more buccal path to emerge into the mouth, or causing its impaction between the lateral incisor and first premolar. Thus Jacoby (1983) found that arch length deficiency was the major factor in buccally impacted canines.

Palatally impacted canines are not associated with the same degree of arch length deficiency and may even have excess space available within the arch (Jacoby 1983). Excess space may arise from increased maxillary alveolar growth or small, peg or absent lateral incisors.

iv. Obstruction

a. Supernumerary teeth

The presence of unerupted supernumerary teeth has been reported as a cause of impaction of canines (Fastlicht, 1954; Thilander and Jakobsson, 1968). Hitchin (1956) reported cases with supernumerary teeth in a series of 109 canine impactions. He also mentioned the difficulty in diagnosing late developing, poorly calcified supernumerary teeth which may be present overlying the impacted canine.

b. Dentigerous cysts, dental follicles and alveolar soft tissues.

Although the definitive diagnosis of a dentigerous cyst can only be made on histological examination, the presence of an enlarged follicular space (greater than 2 mm) on a radiograph may indicate the possible presence of such a cyst. Using this criterion, Thilander and Jakobsson (1968), in their longitudinal study of school children found that although widening of the follicular space was fairly commonly associated with failure of the canines to erupt, there was no convincing evidence that this was the cause of the impaction. However a greatly enlarged follicular

space might presumably interfere with eruption since internal pressures would be expected to produce forces opposing eruption and thence cause impaction. Although the relatively high incidence of 70% of the impacted canines in children and 61% in the adult group showed enlarged follicular spaces, Thilander and Jakobsson had difficulty in considering this as a cause of the impaction.

On the other hand, Di Biase (1971) found that the soft tissues overlying the crowns of teeth with delayed eruption showed histologically a sharply demarcated layer of immature oedematous connective tissue in the submucosa, separate from the tissues within the mucosa. This sharp demarcation between the two layers was, he felt, evidence that a physical barrier was present (rather than just a slowing of the normal eruptive process) particularly as, in some sections, a separate fibrous band could be seen at the junction of the two layers. Di Biase's interpretation was that as the tooth erupts accompanied by its dental follicle it must, at some stage, penetrate both the follicle and the mucosa for emergence to occur. Any failure in the breakdown of the follicle or mucosa would produce a barrier to eruption. He concluded that it appeared to be remnants of an enlarged dental follicle, rather than the mucous membrane, that was likely to cause a delay in tooth eruption. The only evidence of mucosal changes forming a direct barrier were when there was either epithelial hyperplasia or scarring within the tissues overlying the tooth.

c. Odontomata

These are uncommon odontogenic tumours which have been found obstructing the eruption of teeth and therefore have been included in the aetiology of impaction by Thilander and Jakobsson (1968).

There has been no reporting on the type of odontoma related to impaction of canines.

v. Cleft Palates

Unilateral or bilateral clefts of the alveolus and palate occur in the region of the lateral incisor and canine, and may cause considerable disturbance to their development and eruption. The presence of supernumerary teeth impeding the eruption of permanent canines is also more frequently found in patients with cleft palate than in those without clefts. (Hitchin, 1956; Shafer, Hine and Levy, 1974; Graber, 1972).

Attention to the eruption of canines into the region of the alveolar cleft has been emphasized in recent years with the acceptance of bone grafting into the cleft at approximately 9 years. This allows stabilization of the fragments, and bone within the alveolar arch for the canine to erupt into. This technique is now becoming a standard procedure in the management of the patient with cleft palate.

vi. Ankylosis

Ankylosis of deciduous molar teeth has been reported (Shafer, Hine and Levy, 1974), however no report of ankylosis of deciduous canines can be found, notwithstanding the frequency of prolonged retention of this tooth. No evidence of canines "submerging" as is common with the ankylosing deciduous molar could be produced.

Although used by Cranin and Cranin (1968) as a local factor, ankylosis of the permanent canine has not been reported in the literature as a cause of delayed eruption of the canine. There is ample evidence of ankylosis following trauma or surgical intervention, but none of this problem arising spontaneously.

2.3.2 SECONDARY (SYSTEMIC) CAUSES

Secondary causes encompass the systemic factors which may effect the eruption of teeth in general, rather than specifically the canines. A brief discussion is included for completeness.

i. Hereditary disorders

Cleidocranial dysostosis is a prime example of hereditary disorders that delay eruption or cause impaction of permanent teeth. (Shafer, Hine and Levy, 1974; Turner, 1980; Cranin and Cranin, 1968; Moss, 1971). The outstanding dental feature of this condition is the prolonged retention of the deciduous teeth, and subsequent delay or failure in eruption of the secondary teeth. (Shafer, Hine and Levy 1974).

Among other hereditary disorders, the Gorlin and Goltz syndrome, hereditary gingival fibromatosis, cherubism and Gardner's syndrome have been associated with delayed eruption or impaction of permanent teeth.

ii. Endocrine disorders

Both pituitary dwarfism and hypothyroidism have been shown to delay eruption of deciduous teeth which consequently delays eruption of the permanent teeth. (Turner, 1980; Cranin & Cranin, 1968).

iii. Vitamin D deficiency

Rickets retards the eruption rate of the deciduous and permanent teeth according to Shafer, Hine and Levy (1974) and is an aetiological factor in canine impaction. (Bistara et al 1976, Cranin & Cranin 1968, Shafer, Hine and Levy 1974).

2.4 STATISTICS

2.4.1 INCIDENCE OF IMPACTED MAXILLARY CANINES

The incidence of patients with impacted maxillary canines averages approximately 2 per cent, as indicated in the summary of major surveys set out in Table 1. The more extreme variations from this average can be explained by closer examination of the patients sampled. These variations are discussed below.

Reported incidences range from 1.2 per cent (Kramer and Williams, 1970) to 12.9 per cent (Thilander and Myrberg, 1973). The low figure reported by Kramer and Williams may reflect the fact that the survey was done in an Oral Surgery Department in a hospital which had a patient group consisting of 95 per cent negroes. This figure does not necessarily reflect the incidence in the general community, and may indicate that a lower number of canines are impacted in the Negroid race compared to Caucasians, which make up the remaining surveys. The Thilander and Myrberg 1973 study was their second survey of children referred to their orthodontic practice for consultation or treatment and could be expected to be a higher figure than in the general community. Thilander and Myrberg also reported on their longitudinal study of school children at ages 7, 10 and 13 years, with an incidence of 2.2 per cent, which could be considered high as some teeth may erupt spontaneously after 13 years of age, but is not inconsistent with the overall community average of approximately 2 per cent.

TABLE 1: LITERATURE REVIEW: INCIDENCE OF IMPACTED MAXILLARY CANINES

Study		No of Patients Surveyed	Incidence of Impaction		
			No of Patients	%	No of Teeth
Blum,	1920	457*	99		NA
Rohrer,	1929	3,000	64	2.06	73
Dachi & Howell,	1961	1,475	25	1.69	28
Nordenram & Stromberg,	1966	NA	374		500
Bass,	1967	9,102	150	1.65	175
Rayne,	1969	12,000	176	1.5	221
Kramer & Williams,	1970	3,745	45	1.2	NA
Aitasalo, Lehtinen & Oksala,	1972	4,063	120	2.95	147
Thilander & Myrberg,	1973(a)	5,459	121	2.2	NA
	1973(b)	939	121	12.9	NA
McKay,	1978	NA	878		1,029
Buchanan,	1984	NA	1,644		2,001

* with impacted teeth

2.4.2 SEX DISTRIBUTION

All studies showed a greater incidence of impacted canines in females, with the ratios varying from 1 male to 1.5 females (Rayne 1969) to 1 male to 3.6 females (Dachi and Howell 1961), average 1 male to 2.4 female (Table 2). No explanation for this variation is presented in the literature.

2.4.3 UNILATERAL OR BILATERAL IMPACTIONS

In cases with maxillary canine impaction, approximately 20% of patients (range 8% to 33%) had both maxillary canines impacted. Of the major variations from this average, Dachi and Howell's low figure of 8% may be explained by the high number of patients who were over 20 years of age, 1231 patients of their 1475 sample.

The distribution between canines impacted on the right or the left of the arch shows either equal distribution or a slight predominance on the left side in all the studies except Rohrer (1929) who had 42 per cent on the left and 58 per cent on the right. (Table 3).

TABLE 2: LITERATURE REVIEW: SEX DISTRIBUTION OF PATIENTS WITH IMPACTED MAXILLARY CANINES

Study		Ratio: Male	:	Female
Rohrer,	1929	1	:	2.5
Dachi & Howell,	1961	1	:	3.6
Nordenram & Stromberg,	1966	1	:	1.8
Bass,	1967	1	:	2.2
Rayne,	1969	1	:	1.5
Johnson,	1969	1	:	3.0
McKay,	1978	1	:	2.7
Buchanan,	1984	1	:	2.3

TABLE 3: LITERATURE REVIEW: INCIDENCE OF UNILATERAL AND BILATERAL IMPACTATIONS OF IMPACTED MAXILLARY CANINES

Study		Left	Right	Bilateral	Bilateral
		No	No	No	%
Rohrer,	1929	23	32	9	14
Dachi & Howell,	1961	23 (unilateral)		2	8
Nordenram & Stromberg,	1966	260	240	125	33
Bass,	1967	68	57	25	17
Rayne,	1969	104	103	44	25
McKay,	1978	360	367	151	17
Buchanan,	1984	671	616	357	22

2.4.4 SITE OF IMPACTION IN THE ARCH

The canine can become impacted in three areas of the alveolus;

- the buccal or labial aspect
- the palatal aspect
- in the line of the arch.

Some authors have described only two positions, the buccal and palatal, probably because they have approached the tooth surgically from either aspect, which does alter the relative percentages.

Of the papers which categorized three sites, the incidence was 34 per cent buccal, 12 per cent in the arch and 54 per cent palatal (Nordenram and Stromberg, 1966) and 11 per cent, 15 per cent, 74 per cent (McKay 1978). The range for simply comparing buccal and palatal sites was 16 per cent buccal, 84 per cent palatal (Rayne 1969) to 9 per cent buccal, 91 per cent palatal (Bass 1967). If we add the teeth described in the line of the arch to the palatal group then fairly good agreement is reached with an average percentage of 17 on the buccal and 84 palatal. (Table 4).

TABLE 4: LITERATURE REVIEW: SITE OF IMPACTATION OF MAXILLARY CANINE IN THE ARCH

Study		% Buccal	% Palatal	% In-Line-Of-Arch
Rohrer,	1929	22	63	15
Nordenram & Stromberg,	1966	34	54	12
Bass,	1967	8.6	91.4	-
Rayne,	1969	16	84	-
McKay,	1978	11	74	15
Jacoby,	1983	13	87	-
Buchanan,	1984	17	64	19

2.4.5 RETAINED DECIDUOUS CANINE

Only three papers reported on the incidence of retained deciduous canines in patients with impacted permanent canines. McKay (1978) had an 81 per cent incidence, Buchanan (1984) 46 per cent, Thilander & Jakobsson (1968) 60% in children, 20% in adults. The difference may reflect the age group of patients, as one would expect fewer retained deciduous canines in the adult compared to the early teenage group.

2.4.6 PERMANENT LATERAL INCISORS

Two aspects of the relation of the permanent lateral incisor and impacted canines are important.

i. Absence, peg shape or small size of permanent lateral incisor.

The only paper to present the incidence of peg-shaped permanent lateral incisors associated with impacted canines was that of Jacoby (1983), who found 8.7 per cent in 46 cases. The incidence of absent lateral incisors was given by Jacoby as 4.3 per cent. Becker, Smith and Behar (1981) looked specifically at the incidence of absent, peg-shaped and small lateral incisors, but unfortunately they included erupted, palatally displaced canines as well as impacted ones, so their figures cannot be used for direct comparison. They found 5.5 per cent absent, 17.2 peg-shaped and 25 per cent small when compared to the lower incisor.

ii. Resorption of the permanent lateral incisor

Destruction of part or all of the root of the permanent lateral incisor by the impacted canine was reported by Kettle (1957) and Brown and Matthews (1981). The incidence appears to be consistent in three surveys reporting it - McKay (1978) 1.2 per cent, Rayne (1969) 1 per cent, Buchanan (1984) 1.8 per cent and an unexplained higher incidence in Hitchin's paper (1956) of 5.4 per cent.

2.4.7 SUPERNUMERARY TEETH, ODONTOMATA AND FOLLICULAR ENLARGEMENT

The obstruction or displacement of the canine by either a supernumerary tooth or odontoma was reported with an average incidence of 2.6% (Bass 1967, McKay 1978, Rayne 1969, Thilander and Jakobsson 1968).

Radiographic evidence of follicular enlargement of greater than 2 millimetres was used by Thilander and Jakobsson (1968) to indicate cystic changes in the dental follicle. They found that 70 per cent of children, and 61 per cent of adults had enlargement. These figures are much higher than the other reports of follicular enlargement. 0.2 per cent McKay (1978), 4 per cent Rayne (1969) and 9.7 per cent Hitchin (1956). As presented in the section on the aetiology of impaction, Thilander and Jakobsson concluded that there was no convincing evidence that follicular enlargement was the cause of the impaction.

2.4.8 AGE DISTRIBUTION

Several papers reported on patients of 20 years and older (Aitasalo, Lehtinen and Oksala (1972), Dachi and Howell (1961) which may bias their figures as many impacted canines could have been removed or repositioned prior to that age. Others, Rayne (1969), McKay (1978), included all ages together, without any attempt to break them into groups.

Buchanan (1984) broke down his cases into age groups with 4 per cent below the age of 12 years, 76 per cent between 12 and 15 years, 14 per cent 16 to 18

years and 6 per cent older than 18 years. Ohman and Ohman (1980)on the other hand found a greater number of impacted canines in the younger group; 17 per cent before 12 years, and a greater spread through the teenage years, 59 per cent 12 to 15 years, 17 per cent 16 to 20 years and 7 per cent 20 years or more (Table 5).

TABLE 5: LITERATURE REVIEW: AGE DISTRIBUTION OF PATIENTS WITH IMPACTED MAXILLARY CANINES

Study	Under 12 %	12-15 %	16-20 %	Over 20 %
Ohman & Ohman, 1980	17	59	17	7
Buchanan, 1984	4	76	14	6

The longitudinal study of Thilander and Jakobsson (1968) sheds more light on the decreasing incidence throughout the teenage years as they showed that a number of canines will still erupt during this period. Condensing their results they showed that

- at 12 years, 142 patients had at least one unerupted canine
- between 12 to 15 years this dropped to 11 patients
- between 16 to 19 years a further 3 cases erupted spontaneously.

The differences certainly do not indicate that many teeth are being operated on which may still erupt naturally. However they do indicate that some canines will need keeping under observation for longer than may be indicated by eruption times in orthodontic texts. (Graber 1972).

2.5 ASSESSMENT OF IMPACTED MAXILLARY CANINES

The basis of treatment planning relies on information gathered during both the clinical and radiographic assessments. A thorough medical and dental history is taken and recorded, followed by a general examination, before proceeding to the specific assessment of the canine.

The comprehensive assessment by Rayne (1969) is presented which allows a detailed classification of impacted canines to be formulated.

2.5.1 CLINICAL ASSESSMENT

After taking and recording the patient's history the first step should always be careful examination of the patient's mouth and study models. A great deal of information concerning the position of an unerupted canine may be gained by consideration of the angulations of the adjacent erupted teeth. The maxilla in the canine region is pyramidal in shape, with the roots of the erupted teeth occuping the major part of the alveolar process. An indication of the position of the crown of the unerupted canine may be gained by observing the displacement of the roots of the lateral incisor or first premolar tooth.

The apex of a lateral incisor may be displaced labially by a palatal canine. The apex of the canine is often on the buccal side of the arch, and the apex of the first premolar may be displaced palatally, causing the buccal cusp to be higher than the palatal cusp. It may be possible to see the bulge of the palatal mucosa produced by the crown of the unerupted canine. Conversely, the root of the lateral incisor may be displaced palatally by a

buccal canine and the apex of the canine is usually in the line of the arch in such cases. The canine apex may be palatal to the arch, so that the apex of the first premolar is displaced buccally, with the result that the buccal cusp is lower than the palatal cusp. When the crown of the canine is in the line of the arch, it may cause the lateral incisor to adopt a distal inclination, with the apex displaced mesially, spreading the teeth like a fan.

On palpation, a bulge in the palate in the absence of a canine crown in the arch on the same side is strong evidence in favour of palatal impaction of that tooth. The root of the deciduous canine gives rise to a vertical ridge on the labial surface of the maxilla. This ridge must be differentiated from the more diffuse bulge produced by the crown of the premanent canine, and the permanent canine is becoming displaced towards the palate, the root of the deciduous canine is still palpable at the age of about 10 years. In normal development, the permanent canines can be palpated in the labial sulcus from the age of eight years. When the crown of the permanent canine can be palpated above the lateral incisor, a buccal displacement of the canine is developing. The root apex of a palatally displaced canine can sometimes be palpated above the first premolar crown.

2.5.2 RADIOGRAPHIC ASSESSMENT

When the canine is deeply placed, little information may be gained by clinical examination. A careful radiographic technique is necessary to localize such teeth and to provide vital information of the tooth and its immediate environment. Hunter (1981) presented a detailed coverage of radiographic techniques in his article entitled "The Radiographic

Assessment of the Unerupted Maxillary Canine". He stated that "accurate radiographic assessment must include morphological detail of the unerupted canine and the surrounding structure, together with localization within the dento-alveolar structures of the maxilla". The information required from radiographs should include:

Morphological detail

- morphology of the apex of the canine
- root resorption of adjacent teeth
- degree of resorption of the deciduous canine root
- size of the follicle of the canine
- caries and periodontal health of adjacent teeth.

Localization detail

- bucco-palatal position of the crown
- position of the root apex
- height of the crown relative to the occlusal plane
- obliquity of the long axis of the canine

. proximity to the midline.

The morphological details are obtained on any of the routine dental radiographs. However, more specialized films and techniques are required for localization of the unerupted tooth. The localization of these teeth is extremely important in allowing the assessment of prognosis, and treatment planning to be performed prior to any surgical intervention.

Hunter discussed the radiographic methods for localization as follows:

(i) Parallax localization

This technique of localization employs the use of two or more dental films with a tube shift between each exposure. The original method (Clark 1910) utilized three periapical films, but today, two films are placed successively in the same position and exposed using two different directions of the x-ray tube. Usually the same plane is used with a 20 to 30 degree shift of the tube between each exposure.

If two objects are observed at different angles their relative position changes due to parallax. The more distant object travels in the same direction as the tube shaft, while the nearer object travels in the opposite direction.

Parallax localization may also be applied to an occlusal radiograph as well as a periapical radiograph (Rayne 1969). Either a true or upper anterior occlusal film may be used, the tube shift being from a position in the medial sagittal, distally to a lateral position for the periapical exposure situated directly over the unerupted canine. The unerupted canine will appear to move relative to the adjacent teeth, and the same principles of parallax localization apply.

Parallax localization is possible with panoramic radiography if the Panorex x-ray machine is used. (Turk and Katzenell 1970, Bishara et al 1976, Hunter 1981). The film produced by this machine gives two images of the incisor region separated by a characteristic white shadow. The patient is moved laterally in the chair midway through taking the film giving the movement necessary for the parallax technique. Movement in the same direction as the tube means the canine would be buccally or labially placed. It should be remembered that :-

1. the side of the radiograph used to determine the tube shift is also used to determine the direction of canine movement.

2. that the tube passes behind the patient so the normal rules of parallax are reversed.

(ii) Stereoscopy

Stereoscopy is the method of obtaining perspective or depth in radiographs. The technique involves taking two films, each

representing the image from one eye. The films are taken with the tube moved by approximately 6 centimetres and are usually upper occlusal films. This means the exposure is centred over, initially, the left and then the right eye. The films produced are viewed with a stereoscopic viewer which blends the two images into one, giving an illusion of depth.

(iii) Panography

The panograph is an x-ray machine which is able to produce a magnified panoramic picture by using an intra-oral tube to expose a film placed extra-orally around either the maxilla or mandible.

Localization of unerupted canines has been described by Otrofsky (1976). The intra-oral tube produces almost a point source of radiation and divergent x-rays provide a magnified image of the teeth. The image produced on the film will always be larger than the object itself, and an object placed nearer the tube will produce an image larger than an object of the same size, but placed further away. By comparison of the size of the unerupted canine with that of a normally positioned one on the other side of the arch, the bucco-palatal position of the unerupted canine may be determined. If the unerupted tooth is larger than the reference canine, then it must be nearer the source, or palatal; if it appears smaller, then it must be buccal.

(iv) Localization by views taken at contrasting angles.

Localization is possible by using standard views taken in dental radiography showing the unerupted tooth in different planes, allowing the observer to construct a three dimensional mental image. Both extra and intra-oral views are used, and accurate localization should utilize at least two different planes. The views most commonly suggested are intra-oral periapical and occlusal films, and lateral and postero-anterior cephalometric films. (Helmore 1954, Hitchin 1956, Wraith 1969, Moss 1971, 1975, Bishara et al 1976, Hunter 1981, Williams 1981). Grouping these films for diagnostic purposes has been presented by Hunter (1981):

Group 1 The lateral cephalometric, the P.A. cephalometric and the periapical radiographs.

The lateral and P.A. cephalometric views provide valuable information regarding the position of the canine in the maxilla, while the periapical radiograph provides more detailed information of the canine and its surrounding structures. When viewed on the P.A. radiograph, the relationship of the crown of the canine to the mid-line and the lateral angulation of its root should be considered. From the lateral radiograph, the relation of the crown to the incisor roots, its height above the occlusal plane and the obliquity of the long axis should all be noted.

Group 2 The vertex occlusal, lateral cephalometric and periapical radiographs.

The vertex occlusal radiograph, taken with the x-rays directed parallel to the long axes of the maxillary teeth, is frequently used for bucco-palatal positioning of the canine. The relative clarity of its outline, as compared to adjacent teeth, provides some information regarding its proximity to the occlusal plane, and frequently the root position can be assessed from the inclination of the crown. A clear outline of the root apex implies considerable displacement from the normal position. In conjunction with the lateral skull radiograph the inclination and height of the canine become clear. The periapical radiograph again provides detailed morphology of the canine and the surrounding structures.

Group 3 The upper anterior occlusal radiograph, a lateral radiograph of the anterior maxillary region, and the periapical radiograph.

The upper anterior occlusal radiograph may be used in conjunction with the periapical view for parallax localization as described earlier. This view provides a clear picture of the crown of the canine and its relation to the mid-line: also some indication of the height of the tooth in the vertical plane may be gained by the degree to which the incisor roots are obscured by the crown of the canine. Further information regarding the axial inclination may be obtained by taking a lateral view using the standard dental x-ray set. The film (normally used for oblique lateral radiograph) is held by the patient against the side of the face at right angles to the central ray.

This group provides limited information regarding the position of the apex of the unerupted canine, but requires no special x- ray equipment and is a method readily used in most dental surgeries.

(v) Radiation dosage

The number and type of radiographs necessary for accurate diagnosis must be tempered with the amount of radiation the patient will receive in obtaining them.

Wraith (1969) showed a comparative table of skin exposures and pointed out the high radiation dosage of the vertex occlusal films. The use of these films must therefore be carefully considered.

Skin Exposure to Radiographs

View	Dosage
Lateral Skull	0.08r
Postero-anterior skull	0.13r
Intra-oral apical	0.39r
Standard occlusal	0.6r
Vertex occlusal	1.2r

2.6 CLASSIFICATION OF IMPACTED CANINES

The objective of the assessment is to allow a classification of the problem canine which leads to a diagnosis and treatment plan.

The important areas of the classification are the position of the canine crown and apex and its longitudinal axis. (Moss 1971). Using some, or all of these criteria, several classifications have been proposed. (Nordenram and Stromberg 1966).

Adamson (1952) formulated three groups according to the canine orientation relative to the horizontal position:

Group 1.

The canine is either labial or palatal in relation to the incisor teeth and approaches the vertical position with the root apex lying more or less in the correct position.

Group 2.

The canine is more deeply placed on the palatal side of the arch with the root apex slightly distal to normal, and the incisal tip may extend to a position approximating the mesial surface of the lateral incisor crown.

Group 3.

The canines are, to all intents and purposes, completely horizontal and palatal to the upper incisors. The root apex lies as far distally as the first premolar or even beyond. The incisal tip lies behind the upper central incisors and may even approach the midline. Most are deeply placed and may even approach the floor of the nose.

This classification by Adamson, an orthodontist, allowed him to present treatment alternatives and prognosis for the orthodontic management of canines.

Hitchin (1956) gave a classification which he felt was convenient for oral surgical purposes:

Type 1. canine palatal near the gingival margin (of the adjacent erupted teeth)

Type 2. canine palatal away from the gingival margins

Type 3. canine in labio-buccal position

Type 4. canine in the arch of the roots

Type 5. canine with crown palatal and apex buccal, or above the buccal root of the first premolar

Type 6. rare impactions

Type 7. edentulous patients.

This classification is more orientated to the bucco-lingual than the horizontal position, and orientation is expanded by Archer (1975) who divides impacted canines into five classes.

Class I Impacted canines located in the palate

1. Horizontal
2. Vertical
3. Semi-vertical

Class II Impacted canines located in the labial or buccal surface of the maxilla

1. Horizontal
2. Vertical
3. Semi-vertical

Class III Impacted canines located in both the palatal process and labial or buccal maxillary bone eg. the crown is on the palate and the root passes through between the roots of the adjacent teeth in the alveolar process, ending in a sharp angle on the labial or buccal surface of the maxilla.

Class IV Impacted canines located in the alveolar process, usually vertically between the incisor and first premolar.

Class V Impacted canines located in an edentulous maxilla.

The most detailed classification was presented by Rayne (1969) and allowed all of the variations in position and angulation to be graded, with a treatment alternative presented for each grade. These are:

A. Position of apex:

Grade 1. Vertically above the first premolar root.

Grade 2. Vertically above the interdental space between first and second premolars.

Grade 3. Vertically above second premolar.

Grade 4. Posterior to grade 3 or anterior to grade 1.

B. Height of cusp of canine:

Grade 1. At level of necks of incisor teeth.

Grade 2. Between grades 1 and 3.

Grade 3. At level of apical third of incisor roots.

Grade 4. Above incisor roots.

C. Obliquity:

Grade 1.	60-95 degrees to occlusal plane.
Grade 2.	45-60 degrees to occlusal plane.
Grade 3.	30-45 degrees to occlusal plane.
Grade 4.	0-30 degrees to occlusal plane.

D. Buccal Displacement:

Grade 1.	Related to lateral incisor.
Grade 2.	Not applicable.
Grade 3.	As Grade 1 but above reflection of sulcus.
Grade 4.	Cusp approaching midline.

E. Palatal Displacement:

Grade 1.	Related to lateral incisor.
Grade 2.	Related to central incisor.
Grade 3.	As grade 1 and 2 but high in the alveolus.
Grade 4.	Partial transposition.

Rayne believed that the grades of severity were useful as a "rule of thumb" when considering treatment. A decision was made on the basis of the most unfavourable grade which occurs for any criterion. His grades were related to the treatment plan as:

Grade 1.	Exposure without traction is sufficient.
Grades 2. and 3.	Traction to attachment on the canine.
Grade 4.	Neither traction nor exposure indicated; either remove the canine or leave in situ.

The gradings are useful in surgical assessment as they can be used to assess the surgical difficulty in obtaining access to the impacted tooth and the type of surgical attachment which may be applied to it. They also give an insight into the areas of orthodontic difficulty in the repositioning of these teeth.

2.7 SURGICAL MANAGEMENT OF IMPACTED PERMANENT MAXILLARY CANINES

A large amount of literature exists describing all aspects of surgical management of the impacted canine. In this Treatise I intend to give only a brief overview of the techniques involved in many aspects of the management of these teeth, and to concentrate on the techniques involved in encouraging the canine to erupt and be positioned into the normal place within the dental arch.

2.71 LEAVE IN SITU

In any discussion on surgical management there must be a place for non-intervention, and the judicious observation over a long period of time. Hunter (1983), Killey, Seward and Kay (1971) gave their indications for the retention of the impacted tooth.

i. where the canine is asymptomatic

ii. where the extraction or exposure would damage adjacent teeth

iii. where there is no pathological condition associated with the tooth.

In such situations the decision to retain the tooth is made by the patient after a thorough examination and discussion with the clinician.

The long term problems which may arise from the retention of these teeth are:

i. pain

ii. abscess formation

iii. periodontal pocketing in adjacent teeth

iv. localized ulceration and inflammation beneath a dental prosthesis

v. internal resorption

vi. loss of vitality of adjacent teeth

Azaz and Shteyer (1978) examined the clinical and radiographic data of 252 maxillary impacted canines and found 36 (14%) cases of internal resorption; 19 (53%) in the age group 40 to 60 and 12 (33%) in patients over 60 years. In 31 cases an inflammatory local factor, such as non-vital adjacent teeth, periodontal pockets, or longstanding local irritation of dentures was detected. Only in 5 cases was no pathosis noted.

These results indicate that although a decision may be made at an early age to retain an asymptomatic impacted tooth it may not always remain that way.

2.7.2 SURGICAL REMOVAL

Surgical removal is indicated in several circumstances.

i. Where pathosis is associated with it such as a cyst, tumour or severe resorption of the adjacent teeth (Howard 1970, Moss 1975, Hunter 1983).

ii. Where the orthodontist feels the canine is too poorly placed to be suitable for orthodontic repositioning (Adamson 1952, Moss 1975, Hunter 1983).

iii. Where, following consultation with an orthodontist, the patient is content with a first premolar in intimate and well aligned contact with the lateral incisor (Moss 1975, Ratcliffe 1977, Hunter 1983).

As with the retention of the impacted canine, the decision to remove it is the patient's, after advice from a suitably experienced clinician (Moss 1975).

2.7.3 TRANSPLANTATION OR SURGICAL REPOSITIONING

A large amount of literature pertaining to the canine transplantation and repositioning exists, which will not be reviewed here, as the very recent article by Eliasson, Laftman and Strindberg (1988) summarises the current concept on the status of transplantation. The technique involves the extremely careful surgical removal of the canine from its impacted position, the preparation of a receptor site and then the splinting of the tooth using orthodontic arch wires, acrylic splints or surgical cement for a period of

approximately 3 weeks. The concurrent use of an antibiotic and antiseptic mouth rinse is indicated. At approximately 1 to 2 weeks remove the necrotic pulpal tissues and commence intermediate root canal filling using calcium hydroxide. This may be left for up to 6 months before final obturation with gutta-percha. The use of immediate root canal therapy is an attempt to prevent resorption of the transplant, leading to its loss. Eliasson et al showed successful transplantation in 72% of their canines, with a follow-up over 4 to 5 years. This is, in the author's opinion, representative of the current long term success of canine transplantation.

2.7.4 SURGICAL EXPOSURE OF THE IMPACTED CANINE

i. Theoretical Considerations

The surgical exposure of the impacted canine is done in the belief that the majority of teeth will erupt if all bony and soft tissue covering or any other obstructions are removed from the path of eruption (Clark 1971). This practice was followed for many years based on clinical evidence, until Howard (1978) hypothesized that by exposing the tooth to the oral environment and achieving a continuous attachment between the mucosal epithelium and the dental follicle, that a similar situation to that of marsupialization of a cyst would exist, in so far as the tooth crown forms a wall or part of the epithelialized cavity. He stated that a marsupialized cystic cavity reduces in size by osteogenic activity around the periphery as reparative changes take place, the epithelialized area reduces in size as bone is laid down deep to this tissue and the cavity becomes shallower until the defect is repaired and the normal contour re-established. The tooth crown when exposed forms part of the wall of

such a bony cavity and as the bone defect reduces in size and the epithelial lining approaches the free mucosal surface the tooth is carried along with the reparative changes almost as an unwilling passenger.

Ohman and Ohman (1980) also hypothesized that the mechanism of tooth movement following surgical exposure is not eruption in the normal sense but that of a healing marsupialized bone cavity. In their study, a change of angulation was the most frequent feature in the period directly following surgical exposure. This phase of eruption usually proceeded rapidly, and after the change in angulation the rate movement was reduced in comparison to normal tooth eruption. There is also evidence that the forces influencing the tooth after surgery do not originate in the apical region as many teeth with curved roots rotated around a transverse axis and erupted in a direction diametrically opposed to what could be anticipated from the curvature of the root. Ohman and Ohman also stated that eruption of a tooth following surgery was not significantly influenced by root development. The role of wound contraction related to the presence of myofibroblasts (contractile fibroblasts) in the granulation tissue following surgery was mentioned but not discussed in detail.

ii. Surgical Techniques

The surgical techniques used to expose the unerupted canine vary depending on its position within the maxillary bone, and will be discussed under the headings of Labial Impaction and Palatal Impaction.

A. Labial Impaction

The simplest form of exposure of the unerupted canine is the excision of all the soft tissues and bone overlying the crown (Strock 1938) and possibly along the intended path of movement (Revell 1964).

This technique was still being supported in 1971 by Clark who advocated the "simple complete exposure" for labially placed canines. Even more recently this technique of excision of overlying tissues was presented in the text Oral Surgery in Dental Practice by Kruger and Worthington 1981. In his 1971 text "Minor Oral Surgery", Howe was advocating care to keep the removal of labial mucoperiosteum and bone to a minimum amount required to expose the tooth. He reported some orthodontists concern that the cervical margin of an exposed tooth remained at a higher level than that of its neighbours when eruption was complete.

Also expressing concern over the long term gingival health of labially exposed canines was Di Biase (1971) who found that exposure in non-function buccal mucosa above the muco-gingiva junction led to a long clinical crown, higher gingival attachments and less keratinised tissues, making the area more susceptible to later periodontal disease. This view has been supported by many authors looking at the periodontal health of these teeth (Levin and D'Amico 1974, Heaney and Atherton 1976, Kincaid 1976, Vanarsdall and Corn 1977, Hunter 1983, Boyd 1984).

The first use of an apically positioned flap with a margin of keratinized gingival mucosa was presented by Levin and D'Amico in 1974. Vanarsdall and Corn (1977) expanded this technique and present the results of more than 75 cases. They considered the advantages of providing attached gingiva to the erupting labially placed canine were:-

i. There is no need for a series of dressings or foreign objects to prevent the tooth from being covered by tissue again, even though the tooth may be located above the mucobuccal fold.

ii. The tooth will move rapidly without soft tissue obstruction.

iii. The dentogingival attachment that is created helps to prevent the marginal bone loss and gingival recession often encountered with impacted teeth.

The surgical technique advocated by Vanarsdall and Corn involves an incision along the edentulous area incorporating a keratinized band of attached gingival equivalent height to the adjacent teeth, vertical releasing incisions and then the freeing of the attached gingiva. The connective tissue and bone is then removed from the labial aspect of the crown to beyond the height of contour of the crown. Bone removal is not performed beyond the cementoenamel junction (CEJ) area. The CEJ area is not disturbed as it is here that the new gingival attachment to the tooth is achieved.

It is essential that the gingival tissues be placed to cover the cementoenamel junction area and 2 to 3 mm of the crown for three reasons:-

i. This positioning makes possible the establishment of the supra-alveolar connective tissue attachment to the radicular bone and cementum of the tooth.

ii. The protection of the junctional epithelial seal provided by masticatory mucosa cannot be provided by alveolar mucosa.

iii. The coronal positioning allows some apical movement of the marginal tissue (in long distance movement), because tension develops in the collagenous gingival tissue during movement into the arch. Establishing attachment to the anatomic crown allows the marginal tissue to continue to protect the underlying bone.

Boyd (1984) advocated even less extensive exposure of the labially impacted tooth, uncovering only 4 to 5 mm of cusp tip with 2 to 3 mm of keratinized tissue maintained with either an apically positioned flap or simply excision of overlying tissue providing that if 2 to 3 mm of keratinized tissue could be maintained on the labial aspect. Boyd compared the minimum exposure cases with cases of complete excisional exposure and concluded:

i. that statistically significant loss of attachment, recession and gingival inflammation occur on maxillary canines after surgical exposure of the entire labial aspect of the crown and orthodontic treatment and

ii. the results show that no significant damage occurs to periodontal tissues when the surgical procedure exposes only 4 to 5 mm of the most superficial aspect of the cusp lip while maintaining 2 to 3 mm of keratinized marginal tissue. Both Varnarsdall and Corn, and Boyd stress the importance of plaque control during the surgical management of these teeth to reduce gingival inflammation.

Periodontal health during orthodontic treatment related to width of keratinized gingiva was assessed by Coatoam, Behrents and Bissada (1981) who concluded -

i. Increases in the height of keratinized gingiva may occur on some teeth during orthodontic therapy.

ii. Statistically significant increases in the height of the clinical crown during orthodontic therapy are not reflected in statistically significant decreases in the height of keratinized gingiva.

iii. Minimal widths of keratinized gingiva (less than 2 mm) are capable of withstanding the stresses of orthodontic mechanics.

iv. Teeth that are lacking in any keratinized gingiva prior to orthodontic treatment will not form any new keratinized tissue during the course of orthodontic therapy.

v. Mucogingival problems noted after orthodontic therapy are aften the result of a pre-existing mucogingival problem.

Kohavi, Zilberman and Becker (1984) assessed the periodontal status following the orthodontic alignment of buccally placed maxillary canines, which did not have any surgical intervention. They found that (although of little clinical importance) there was a significant difference between the attached gingiva found on the orthodontically treated canines and that of the untreated controls,with the controls having over 1 mm more attached gingiva than the treated teeth. This still left the treated teeth with more than 3 mm of attached gingiva, which in physiological circumstances, is considered adequate.

The conclusions to be drawn from this evidence are that

i. Orthodontic management requires a sufficient area of healthy attached gingiva before commencing treatment.

ii. Orthodontic movement from a labially displaced position may cause some loss of the gingiva of the canine.

iii. When creating a gingival margin surgically it must consist of an adequate amount of tissue placed into the labial sulcus, with a sufficient width of keratinized mucosa overlying the cervical third of the crown of the canine, allowing attachment to the cervical margin to resist the problems created in positioning this tooth into the arch.

B. Palatal Impactions

The elevation of a palatal flap and the excision of soft tissue and bone directly overlying the unerupted canine is the standard approach for the exposure of this tooth. Variations in extent and siting of the incisions occur, but the basic technique is the same as described by Blum in 1923. Strock (1938) using an electrosurgical scalpel removed soft tissues widely from around the canine which he felt needed wider exposure and was more difficult to expose than any other tooth. Bone removed was by hand pressure chisels, scalers and tiny rongeurs. Removal of the follicle down to the cementoenamel junction was also stressed. Strock maintained the opening with a celluloid crown filled with "ointment" and pressed into place over the canine crown. He also stressed that the use of surgical packs and other materials which become hard should be studiously avoided as they may become an irritant.

a. Surgical Packs and Crowns

Packing materials used are mainly surgical packs containing zinc oxide and eugenol,(Lewis 1971, Archer 1975, Fastlicht 1954, Wisth Norderval and Boe 1976, Whitlock and Hamilton 1968, von der

Heydt 1975) white ribbon gauze and iodoform were used by Mckay (1978) anf Moss (1975). Orahesive bandage was advocated by Johnston (1969). The objective of the pack is to prevent covering or re-epithelialization over the exposed tooth (Hunter 1983) and it is usually left 7 to 10 days (Helmore & Norton 1954) or up to 4 weeks (Lewis 1971, Bishara et al 1976).

The use of the packing material to aid the movement of the canine was proposed by von der Heydt (1975) who softened base plate gutta-percha and introduced it between the labial surface of the crown and the socket so it was wedged into the follicular space. The objective was to force the crown to move away from the proximity of the central lateral incisors and to cause the tooth to erupt towards the oral cavity. A Wond-r-pak dressing was placed over the remaining space. This combination of gutta-percha and surgical pack was repeated at intervals, as each loosened, and fell out, it was replaced until an emerged, bandable tooth was achieved.

The use of plastic or celluloid crowns placed over the crown of the exposed canine at the time of surgery performs the same physical function as the surgical pack. This technique was used by Strock (1938), and by Weiss Jacobs and Rafel (1953), and more recently by Clark (1971) who used plastic crowns filled with surgical cement or paste, extended adequately through the soft tissues into the mouth to facilitate the eruption. There must be some extension from the impacted tooth through the soft tissue to prevent scar tissue forming over the tooth. The success of this procedure is

directly proportionate to the freedom which the crown has in erupting without bony or soft tissue interference.

The success of exposure and packing of palatally impacted canines has been reported by Thilander, Thilander and Persson (1973). With a follow-up of 2 to 7 years the success rate was

45.8 per cent full eruption

15.0 per cent partially erupted

7.5 per cent tending to erupt but covered by mucosa

31.7 per cent no eruption.

McKay (1978) reviewed 461 cases with surgical exposure, with the success rate of over 85 per cent, 4.5 per cent remaining unerupted, the remaining 10 per cent were successful surgically but patients did not continue with treatment.

b. Periodontal Considerations

The periodontal health of surgically exposed and orthodontically moved impacted maxillary canines was always held to be free of problems, (Di Biase 1971, Heaney and Atherton 1976), however on close examination some decrease in bone support, and increase in pocket depth was reported (Wisth, Norderval and Boe 1976, Smyth 1981, Becker, Kohavi and Zilberman 1983, Kohavi, Becker and Zilberman, 1984).

Becker, Kohavi and Zilberman (1983) found a consistent loss of almost 4 per cent in supporting bone following orthodontic

alignment of palatally displaced, surgically exposed maxillary canines when compared to the normally erupted side. The extent of exposure during the surgical procedure was assessed by Wisth, Norderval and Boe (1976) who concluded radical exposure (excision of all overlying bone and soft tissues from the crown) caused greater loss of palatal fibre attachment, and reduced interdental bone height when measured on radiographs than more moderate surgical exposure. Smyth (1981) also found significant reduction in bone height in surgically treated cases, as well as increased pocket depth on the mesial aspect of the aligned canines. The recommendations of all those studies is summarized by Kohavi, Becker and Zilberman (1984) who stated "the most serious damage that occurs in the treatment of a palatally impacted canine is the result of surgical intervention that exposes the buried tooth to beyond its cementoenamel junction and will express itself in the form of loss of bone support. Given the advances in the field of mechanotherapy that are available to orthodontists today, it is considered overzealous surgical procedures no longer have a place in the treatment of these teeth."

The suturing of the soft tissue back over the impacted tooth following bone removed, and possibly some form of direct attachment, has been advocated as a means of protecting the periodontal health of the canine (Ziegler 1977, Hunt 1977), and has been shown to improve the periodontal health (Wisth, Norderval and Boe 1976), although as recommended by Buchanan,

this decision is usually made after the exposure of the tooth as it is difficult to assess its position pre-operatively and if deeply placed and poorly aligned, exposure with packing may be very difficult to maintain.

c. Channelling

The removal of bone from around the impacted tooth and in the direction of desired movement has been suggested by several authors (Buchanan 1967, Whitlock and Hamilton 1968, von der Heydt 1975), with Revell (1964) advocating removal of bone from around the crown and neck of the tooth and then from the root surface down to a point 3 to 5 mm from the apex.

This practice was soundly criticised by Weiss, Jacobs and Rafel in 1953 and is contrary to the current concept of minimal exposure of the tooth and surrounding soft tissues to protect the periodontal health, as discussed above.

d. Stimulation

The term "stimulation" was used by Helmore and Norton in 1954 to describe the careful elevation, of lifting away, of the impacted canine from the roots of the adjacent incisors, to "help" it in its eruption into the mouth. Helmore (1967) and Buchanan (1967) continued to use this technique as a part of the exposure of palatally impacted canines. More recently Clark (1971) and Altonen and Myllarniemi (1976) have recommended the technique, Altonen and Myllarniemi stating that "slight

luxation of the exposed tooth is a useful means of stimulating its eruption, especially in cases where the canine is directed towards the roots of the incisors".

No evaluation of the technique has been presented in the literature and no discussion of the possible sequelae that could result from damage to the cervical aspect of the tooth or ankylosis due to disruption of the periodontal support has been assessed.

2.7.5 ATTACHMENT FOR ORTHODONTIC TRACTION

Attachment to the unerupted canine either at the initial procedure of exposing the tooth, or subsequent to exposure and packing of the tissue space has been frequently advocated to aid the movement at the unerupted tooth into the mouth during orthodontic management. Various methods have been advocated to gain this attachment:-

i. Cementation of cast caps, or pre-formed orthodontic bands

ii. Insertion of cemented or self-tapping pins

iii. Ligation with wire around crown or cervical region

iv. Ligation with wire passed through a hole drilled through the crown.

v. Direct attachment with acid-etch bonding materials.

Prescott and Goldberg (1969) outlined the advantages and disadvantages of some of these and other techniques. Their results are summarised below:

Techniques for orthodontic elevation of deep impactions.

Technique	Advantages	Disadvantages
Exposure	1. Minimal surgery	1. Unsure prognosis 2. Regrowth of bone or gingiva 3. Slow eruption
Exposure with packing	1. Same as above	1. Same as above 2. Poor oral hygiene
Placement of metal or plastic crown cover	1. Satisfactory for shallow impactions	1. Requires cementation 2. Slow eruption
Ligation	1. Rapid, controlled eruption	1. Extensive bone removal 2. Possible injury to adjacent teeth
Surgical repositioning or autogenous transplantation	1. Immediate repositioning and alignment	1. Maximum bone removal required 2. Frequent injury to adjacent teeth 3. Frequent devitalization of impacted tooth
Pinning	1. Minimal injury 2. Rapid, controlled eruption	1. Requires restoration of pinhole

i. Cementation of cast caps or preformed orthodontic band

Weiss, Jacobs and Rafel (1953) presented their technique for exposing and gaining attachment to the unerupted canine by obtaining an impression of the tooth using a fitted copper band filled with Kerr's compound. The soft tissue overlying the tooth was excised and the area packed with plain gauze impregnated with Ward's Wond-r-pak. The pack was removed at four to six days and, under local anaesthesia, a casting made from the impression of the crown was cemented. The casting was very thin, with the necessary loops, staples and brackets soldered in strategic positions to facilitate proper movement of the tooth. The authors stressed that no orthodontic pressure be applied to the tooth immediately following surgery and that light traction or light spring movement can be instituted about one week later.

Fastlicht (1954) used a very similar technique, taking the impression several weeks after exposure and packing of the tooth. Johnston (1969) waited four to six months before manufacturing and cementing a cast onlay. No indication of the type of cement was given by any of these authors.

The use of a pre-formed orthodontic band cemented to the canine was presented by Buchanan in 1967. He stated that it was a difficult procedure in the vault of the palate but of value buccally, particularly if the canine was to be left exposed. The major problem was obtaining a dry field for cementation under surgical conditions interfering with the adhesion of the cement and thus the risk of the band being dislodged was present. This would cause significant problems if the tooth was still

covered by soft tissues, and the band separated from the tooth and pulled into the mouth leaving the tooth behind.

ii. Ligation with Wire

Attachment to the unerupted canine by means of a wire loop tightened around the cervical margin or just coronal to the cervical margin has been described by many authors. (Adamson 1952, Leslie 1955, Revell 1964, Buchanan 1967, Helmore 1967, Adelman 1969, Andreason 1971, Moss 1975, Bishara et al 1976, Shapira and Kuftinec 1981 and Boyd 1982).

Perhaps the best description of this technique was given by Buchanan in1967. This author used a single loop of 0.012 inch (0.3mm) soft stainless steel wire slipped over the exposed crown of the unerupted tooth. The loop was tightened just coronal to the neck of the tooth and the free ends brought through the sutured incision line and attached to an arch wire or finger spring. He presented a series of modified instruments which facilitated the placement of this ligature wire.

A later technique of using a length of 9 carat gold jeweller's chain was considered by Buchanan to be a more ideal method. The chain allowed a straight pull between tooth and appliance facilitating both surgery and orthodontic traction. Buchanan considered the chain easy to handle at the time of surgery and was specially useful during traction as it allowed the unerupting tooth to be brought into alignment one link at a time. It also reduced the risk of wire fracture due to repeated adjustments which cause work-hardening of the wire.

Shapira and Kuftinec (1981) in their paper entitled "Treatment of Impacted Cuspids. The Hazard Lasso" presented three cases of complications to teeth showing cervical resorption associated with ligature wires, and one case of damage to the adjacent lateral incisor occurring during surgery. They are critical of the lasso wire technique as they believe the risk of external root resorption is especially related to this method. They offer the explanation that the wires may be twisted too tightly around the tooth creating continuous pressure on the cementum. This in turn may cause alteration in the cellular activity within this tissue; thus, it is possible that, once started, surface resorption will continue to advance through dentine into the root canal. The authors also stated that the dental follicle of the canine lies very close to the root of the lateral incisor. They believe this can place the periodontal attachment of this tooth at great risk both from the unerupted tooth and from efforts to retrieve or remove it.

Boyd (1982) also presented three cases from a series of eight teeth treated by wire ligation. In all three patients ankylosis was found in the area of external resorption at the cemento-enamel junction and involved more crown than root. He also hypothesised that wire ligation induces loss of periodontal attachment on the proximal and lingual surfaces of the impacted canines, whereas the direct bonding technique did not induce such loss.

Buchanan in personal communication (1984) is critical of the techniques described by both Shapira and Kuftinec (1981) and Boyd (1982), claiming that the ligation of the impacted canine by wire lasso should not be done with the wire tightened to the level of the cemento-enamel junction, as adequate retention can be obtained with the wire

more loosely twisted so that it may lie just apical to the greatest mesio-distal width of the crown, well coronal to the cemento-enamel junction. Placing the wire in this position also allows traction to be closer to the incisal tip of the tooth. Buchanan claims this technique completely avoids any damage to the cervical attachment and eliminates ankylosis of the tooth at this level.

iii. Cemented or self-tapping pins

A direct attachment to the impacted canine by either the cementation of a stainless steel pin or the screwing of a threaded pin (either gold or stainless steel) into the tooth has been presented by several authors.

Dewell (1949) described the technique but was critical of the need to destroy tooth structure and he was concerned with the possibility of pulpal damage.

Kettle (1957, 1958) described in detail his technique of inserting a pin on the palato-distal aspect of the tooth at an angle decided on by the position of the tooth so that the pin emerged through the surgical incision. A hook or acrylic ball was placed on the pin for traction purposes.

Prescott and Goldberg (1969) presented 14 canine teeth which had threaded stainless steel pins inserted into the cingulum area. All teeth were successfully brought into useful occlusion; however, three pins required additional cementation, one pin was dislodged and needed repinning, one canine could not be successfully pinned due to the narrowness of the arch and one canine was found to be non-vital one year after surgery.

Porter and Ryder (1974) described the successful use of pins in 30 patients. A threaded pin was screwed into the enamel ridge or cingulum, or cusp tip. Although not discussed in detail, it was suggested that loose or displaced pins can be cemented back into position and that the only disadvantage of the technique is that a hole needs to be drilled into the tooth, but that this hole is small and restoration can be done easily after the tooth has been repositioned. No mention of pulpal damage was made in this article.

In summary, many authors mention the technique of pinning or gaining attachment to unerupted canine teeth but most dismiss this method as being too destructive of tooth material and potentially injurious to the tooth pulp.

iv. Ligation with Wire using a Hole Drilled through the Crown

Two of the more detailed articles describing the technique of drilling a hole through either the tip of the cusp or the disto-incisal corner of the unerupted canine tooth are those by Buchanan (1967) and Fournier, Turcotte and Bernard (1982).

Both articles stated that the indication for this technique is the deeply placed impacted tooth, to which attachment by any other technique would be extremely difficult if not impossible. Both recognise that damage to the tooth by either too deeply placed holes injuring the pulp, or by superficially placed holes causing fracture of the tooth enamel can occur with inaccurate drilling of the holes, but felt that the risks are justified if no alternative technique is available.

v. Bonded Attachments

With the development and commercial availablity of materials for the acid-etched preparation of enamel for composite resin bonding of attachments to the surfaces of teeth, both surgeons and orthodontists began attempts to gain attachment to unerupted teeth using this technique.

Gensior and Strauss (1974) published the first paper presenting results of 100 cases showing that the use of both a light-cured and chemically activated sealant system were equally effective in gaining attachment to the unerupted canine.

Their technique involved the surgical exposure and packing of the wound for approximately three weeks followed by bonding of an orthodontic bracket or button to the exposed portion of the tooth. Preparation of the tooth by cleaning with pumice or a rubber point was followed by application of the tooth-etching phosphoric acid, irrigation with water and drying. Bonding of the appliances was then undertaken. The authors unfortunately did not present the results of these cases.

Nielsen, Prydso and Winkler (1975) undertook a study to determine

a. whether sufficient bonding can be established without previous pumicing of the tooth surface,

b. whether the use of phosphoric acid causes any harm to the adjacent tissues,

c. whether the necessary dryness of the tooth surface can be obtained during operation.

Their method involved the use of a preformed acrylic bracket, "CUSPID-PULL". Nineteen maxillary canines from a total of 23 teeth were bonded using the technique of the excision of the overlying soft tissue and bone, etching with phosphoric acid (strength not given) for four minutes, irrigation with a saline solution, drying with gauze and then applying primer with a cotton pellet. The "CUSPID-PULL" bracket was then bonded to the tooth surface.

Their results showed that in only 3 cases did the brackets loosen, all occurring late in the treatment. The results demonstrated that

1. sufficient bonding could be established on impacted teeth without pumicing the tooth surface,

2. no harmful effects of the phosphoric acid to the surrounding tissues were seen, and healing was uncomplicated in all cases. The phosphoric acid appeared to assist in preventing bleeding from the pericoronal space during the operation,

3. dryness of the tooth surface necessary for bonding of the orthodontic bracket could be obtained on surgically exposed teeth during the operation.

However, the difficulty in maintaining dryness was emphasised in a later paper by Bishara et al (1976).

The technique published by Hunt in 1977 is similar in many respects to that used in this treatise. Hunt successfully treated 25 cases by bonding a variety of appliances to the unerupted canine tooth. One and a half minutes of etching by a 30% phosphoric acid gel was followed by irrigation with distilled water and drying with warm air from a hair dryer in preparation of the tooth surface for bonding. Hunt sutured the soft tissue flaps back over the unerupted tooth, commencing traction to the tooth immediately. His attachments included orthodontic appliances welded to a base of orthodontic band material with a mesh backing, or 9 carat gold chain wired to stainless steel eyelets or hooks bonded to the tooth.

A similar surgical technique was described by Levine and Skope in 1979, claiming success in 16 unerupted maxillary canines, 7 of which were palatally placed, 8 labially and one in mid arch.

A preliminary report on the early technique leading up to the cases described in this treatise was presented by Mouser in 1980, the surgical procedure being identical with that used in this treatise (described in detail later). The appliance to be bonded to the unerupted canine consisted of a small piece (square/rectangle) of stainless steel band with a steel mesh welded to one surface and a 9 carat gold jeweller's chain welded to the other surface. This appliance offers flexibility in selecting a bonding site on the tooth as it can be bent to fit any enamel surface, including the incisal edge.

Boyd (1982) compared the results of the wire ligation technique and the direct bond of an orthodontic bracket technique. The results indicated that 3 of the 8 patients in the group receiving wire ligation exhibited external resorption and ankylosis while none of the bonded teeth had this problem. Also there was an average of 1.36 millimeters greater loss of attachment in all 4 proximal and lingual probing measurements of teeth ligated with ligature wire compared with the bonding technique.

Fournier, Turcotte and Bernard (1982) often used a direct bonded attachment (bracket or eyelet). They felt, however, that this attachment necessitated complete dryness of the operative field, which is sometimes difficult to maintain. If not perfectly done, there is a risk of breakage during the treatment, thus necessitating a new surgical intervention. As a result, they advocated the drilling of a hole in the tip of the crown, as described in Section iv. above.

Hunter (1983) again stressed the difficulty of the direct bonding technique in maintaining a dry operative field and advocated the

exposure by soft tissue excision and the packing of the wound with subsequent bonding of attachment approximately 3 weeks after exposure, for palatally impacted canines. Labial canines were managed by bonding of an orthodontic bracket and either apically repositioning the labial flap or replacing it over the unerupted tooth to its original position.

The papers presented generally reflect the need for meticulous attention to maintaining the dryness of the operative field during the bonding process. A modification of a suction device allied with the use of warm air from a hair dryer largely overcomes these problems and will be presented in a later chapter.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

The study consisted of 197 cases with 245 impacted maxillary canines. They were all patients treated at the United Dental Hospital of Sydney and were all patients of the Department of Orthodontics. Surgical procedures were carried out mainly by the author; however, other surgeons were involved. All cases were managed using local anaesthesia.

The appliance bonded was manufactured by the author and consisted of a 3 mm by 4 mm piece of wire gauze mesh 90 gauge (British Standard Mesh Number) onto which was welded a 1.5 cm length of Number 33, 9 carat gold jeweller's trace chain by 3 to 5 spot welds. This is a development of that described in the author's article (Mouser 1980). The steel band material was eliminated as the gold chain successfully welded directly onto the mesh. A General Electric Model HD 21 hair dryer was used to deliver warm dry air to the surgery site. Bonding material for all cases consisted of Caulk Solo-Tach, manufactured by L.D. Caulk Company, Milford, Delaware 19963, USA.

3.2 METHOD

3.2.1 SURGICAL PROCEDURE

The procedure was undertaken in an outpatient surgery using local anaesthesia, occasionally supplemented by nitrous oxide relative

analgesia.

Infiltration of the surgical area was undertaken with a local anaesthetic solution containing adrenaline infiltrated into the soft tissues surrounding the crown of the unerupted tooth, including the dental follicle. This markedly reduces bleeding during surgery.

Surgical exposure to allow working space around the unerupted tooth was achieved by the use of standard surgical flaps. The flaps used for canines in both the buccal and palatal positions are described.

i. Buccally placed teeth

a. Suturing of the soft tissue to its original position following attachment

b. Either apically repositioning or rotating the buccal flap and suturing it to the cervical region of the tooth (as per Vanarsdall and Corn 1977).

c. Excision of overlying soft tissue when sufficient keratinised mucosa was available to allow a keratinised gingival margin to be maintained. A pack may or may not be necessary in these cases.

ii. Palatally exposed teeth

a. Suturing of the soft tissue to its original position.

b. Excision of overlying soft and hard tissue and insertion of a periodontal pack to maintain exposure.

c. Excision of overlying soft tissue only.

In all cases the bulk of the dental follicle was left in situ, especially its attachment at the cervical margin.

As the tooth had not previously been exposed to the oral environment and had not formed enamel cuticle it was considered not necessary to use pumice prior to etching. A pledget of cotton wool moistened with "tooth conditioner" (50 percent phosphoric acid by weight) until wet, was then applied to the selected portion of the tooth crown. This was then replaced by a second, drier, pledget which was held on the area to be etched for 60 seconds. A small excess of acid was allowed to flow around the immediate area, thus coagulating any remaining, inaccessible, small bleeding points. Scrupulous attention by the assistant is essential to maintain a dry field, free from contamination by saliva and blood. The use of a modified sucker which allows simultaneous retraction and suction is invaluable at this stage. The tooth was carefully irrigated with distilled or sterile water and dried with warm dry air from the hair dryer. Effective etching produces a uniform chalky white colour. Any contamination at this stage necessitated either re-irrigation or re-etching.

The bonding material was mixed according to manufacturer's instructions and applied to the mesh. The pad was held immobile in firm contact with the crown of the tooth for the required three and one-half minutes from the start of mixing until set. A continuous flow of hot air may be used to accelerate

the set and maintain a dry field, however this was not always used.

The effectiveness of the bond was then tested by a gentle, steady pressure along the proposed line of traction. If this was satisfactory then the chain was ligated to the arch wire or adjacent tooth ensuring that the chain passed through the soft tissue in the direct line of traction. It may be necessary to bring the chain through a stab incision away from the flap margin to achieve this. The direct line, eliminates unnecesary pulling to straighten the chain before tooth movement can occur.

The soft tissue flap was then either repositioned and sutured or an appropriate amount excised and the exposure maintained by a peridontal pack if necessary. Suture material was 3/0 plain cat gut for palatal exposure, and 4/0 for buccal exposure. If packing was used, the pack was maintained in position for approximately 10 to 14 days.

Postoperative analgesia and oral hygiene instructions were given to all patients.

The patient was requested to return to the orthodontist either immediately, or following pack removal.

CHAPTER FOUR

RESULTS

A total of 197 patients involving 245 impacted maxillary canines were examined and treated during this study. The cases were first classified by aetiological assessment and then according to the age of the patient and the condition of the adjacent teeth.

Treatment of 89% of these impactions involved an initial surgical procedure of either bonding or bonding with both exposure and packing. The remaining 11% required only exposure or exposure with packing as a primary procedure.

14.7% (36 in number) of teeth required a second procedure. 67% of these simply involved surgical exposure while 2 teeth (5.5%) involved rebonding and 5 teeth (14%) were extracted. Only 2 cases required a third procedure, one being extracted and one transplanted. In both these cases, the bonding appliance was still in place. These results are tabulated in the sections which follow.

4.1 CLASSIFICATION

Of the 197 patients with impacted maxillary canines 24.4% (48 in number) had bilateral impactions.

All the cases were assessed according to the aetiology of the impactions. The incidence of each type was as follows:-

TABLE 6: SAMPLE SORTED BY POSITION AND AETIOLOGY

Classification Number	Assessment Description	No of Teeth	% of total No of teeth
0	Unknown	20	8.2
1	In line of arch	14	5.7
2	Palatal	173	70.6
3	Labial/buccal	34	13.9
4	Dilaceration	-	-
5	Supernumerary	2	0.8
6	Cleft Palate	2	0.8
	TOTAL	245	100.0

70.6% impacted teeth were assessed as having a palatal position while 13.9% were assessed as labial/buccal. If the "unknown" cases are removed from the sample, these figures rise to 77% and 15% respectively. This is in agreement with previous papers, (McKay 1978). If teeth described as being in the line of the arch are added to the palatal group, the above percentages become 83% and 15% which is consistent with the average noted by past authors of 84% palatal and 17% on the buccal (Table 4).

NB: In 48 cases both left and right maxillary canines were impacted. These are detailed below:-

TABLE 7: ASSESSMENTS IN BILATERAL CASES

Impacted teeth	Classification No.	Description	No of occurrences	% of cases
13-23	2-1	Palatal-in line of arch	3	1.5
13-23	2-2	Palatal-palatal	31	15.8
13-23	3-1	Labial/buccal-in line of arch	3	1.5
13-23	3-2	Labial/buccal-palatal	1	0.5
13-23	3-3	Labial/buccal-labial/buccal	6	3.1
13-23	unknown	unknown	4	2.0
		TOTAL	48	24.4%

The total occurrence of bilateral impacted canines of 24.4% is consistent with the mid range of the work conducted by Dachi and Howell (1961) and Nordenram and Stromberg (1966).

4.2 CONDITION OF ADJACENT PERMANENT LATERAL INCISOR

The condition of the permanent lateral incisor adjacent to the impacted canine was categorised as follows:

TABLE 8: CONDITION OF ADJACENT TOOTH

Category	Condition of Adjacent Tooth	Impacted Tooth	Number of Cases	Total	%	% Adjusted for Unknowns
0	unknown	13	11			
		23	15			
		13-23	8	34	17.5	-
1	normal	13	41			
		23	55			
		13-23	29	125	63.5	77.0
2	small	13	3			
		23	4			
		13-23*	2	9	4.5	5.5
3	peg-shaped	13	8			
		23	3			
		13-23	5	16	8	10.0
4	absent	13	4			
		23	5			
		13-23**	3	12	6.0	7.0
5	resorbed	13	-			
		23	-			
		13-23	1	1	0.5	0.5
		TOTAL	197	197	100	100

* This includes one case with one normal and one small lateral incisor.

** Includes one case of one peg-shaped lateral incisor and one absent lateral incisor and one case with a normal sized lateral incisor and the other absent.

These statistics for peg-shaped adjacent lateral incisors of 8% (10% adjusted) correlate reasonably closely with Jacoby (1983) who observed this condition in 8.7% of cases. The incidence of absent adjacent lateral incisors of 6.0% (7:0% adjusted) also correlates with previous work by Jacoby 4.3%, Bass (1967) 7.0% and Becker, Smith and Behar (1981) 5.5%. The single sample of a resorbed adjacent tooth gives a slightly lower occurrence of 0.5% compared with previous work - Rayne (1969) 1.0%, McKay (1978) 1.2% Buchanan (1984) 1.8% and Hutchin (1956) 5.4%.

4.3 SURGICAL PROCEDURE

With the exception of 27 impacted maxillary canines (11%) where simple surgical exposure or exposure with packing was used, all cases were treated by applying the bonding techniques described in the previous chapter. Bonding was undertaken either in isolation or together with exposure and packing. Where these initial procedures were subsequently deemed to have been insufficient or ineffective a second and sometimes third procedure was applied. The fact that only 13.8% of initially bonded teeth (30 in number) required some form of follow-up surgery (usually exposure) attested to the effectiveness of the bonding technique. Two of these teeth required rebonding due to failure of the appliance during orthodontic traction.

The table below summarises the initial surgical procedures chosen and sorts them according to tooth position and assessment.

TABLES 9A-D: INITIAL SURGICAL PROCEDURE SORTED BY ASSESSMENT AND TOOTH POSITION

TABLE 9A: PROCEDURE: EXPOSURE WITHOUT PACKING

(2.5% of all cases)

Assessment	Teeth Position				
	13 only	13 when 23 also impacted	23 only	23 when 13 also impacted	TOTAL (No.)
in line of arch				1	1
palatal			1	2	3
labial/buccal	1		2		3
TOTAL					7

TABLE 9B: PROCEDURE: EXPOSURE WITH PACKING

(8.5% of all cases)

Assessment	Teeth Position				
	13 only	13 when 23 also impacted	23 only	23 when 13 also impacted	TOTAL (No.)
unknown	1		2		3
in line of arch			1		1
palatal	6	2	1	2	11
labial/buccal		1	4		5
TOTAL					20

TABLE 9C: PROCEDURE: BONDING

(60% of all cases)

Assessment	Teeth Position				
	13 only	13 when 23 also impacted	23 only	23 when 13 also impacted	TOTAL (No.)
unknown	3	3	6	3	15
in line of arch	1		2	1	4
palatal	33	22	34	20	109
labial/buccal	2	5	4	5	16
cleft palate			2		2
TOTAL					146

TABLE 9D: PROCEDURE: BONDING WITH EXPOSURE AND PACKING (29% of all cases)

Assessment	Teeth Position				
	13 only	13 when 23 also impacted	23 only	23 when 13 also impacted	TOTAL (No.)
unknown		1		1	2
in line of arch	4	1	1	2	8
palatal	14	10	17	9	50
labial/buccal	2	3	4	1	10
supernumerary			1	1	2
TOTAL					72

In summary, a simple bonding technique was applied in 60% of operations, while bonding together with exposure and packing was used in a further 29% of operations, resulting in 89% of teeth being treated with a bonding procedure. 2.5% received only exposure while an additional 8.5% were exposed then packed.

4.4 SECOND SURGICAL PROCEDURE

36 teeth required a second surgical procedure. Of these, 67% (24 in number) were exposed, 5.5% (2 in number) were rebonded, 11% (4 in number) were bonded (having been simply exposed and packed as a first procedure) and 14% (5 in number) were extracted. One had an unknown first procedure.

The details of these procedures are set out below:-

TABLE 10: SECOND SURGICAL PROCEDURE

Second Surgical Procedure		Assessment	No. Treated	First Procedure Used
Category	Description			
1	Extraction	unknown	1	Bonding
		palatal	2	Bonding/bonding with exposure
		labial/buccal	2	Bonding (both cases)
		SUB-TOTAL	5	
2	Exposure without packing	palatal	5	Bonding (all cases)
		labial/buccal	1	Bonding
		SUB-TOTAL	6	
3	Exposure with packing	unknown	4	Bonding (all cases)
		in line of arch	1	" "
		palatal	11	" "
		labial/buccal	2	" "
		SUB-TOTAL	18	

Second Surgical Procedure		Assessment	No. Treated	First Procedure Used
Category	Description			
4	Bonding	unknown	1	Bonding with exposure and packing
		palatal	2	Exposure with packing only / Bonding
		labial / buccal	1	Exposure with packing
		SUB-TOTAL	4	
5	Bonding with exposure and packing	palatal	3	Bonding (one), other involved 2 teeth in one patient were exposed & packed initially
		SUB-TOTAL	3	
		TOTAL	36	

These second treatments are summarised further as follows:

TABLE 11: SECOND PROCEDURE SORTED IN ACCORDANCE WITH FIRST PROCEDURE USED

First Procedure		No. Requiring	Second Procedure Used	
Category	Description	Second Procedure	No.	Description
4	Bonding	30	4	Extracted
			6	Exposed
			18	Exposed with packing
			2	Rebonded
5	Bonding with exposure and packing	1	1	Extracted
3	Exposure with packing	4	4	Bonded
0	Unknown	1	1	Bonded
TOTAL		36	36	

Of the 5 teeth extracted during the second procedure, all had the bonding appliance firmly attached at the time of extraction, their removal being requested by the orthodontist.

4.5 THIRD SURGICAL PROCEDURE

Only 2 cases required a third surgical procedure. These were both cases which had received bonding as a first procedure and exposure as a second treatment. One was extracted while the other tooth was transplanted.

4.6 AGE DISTRIBUTION OF PATIENTS

TABLE 12: AGE OF PATIENT AT TIME OF INITIAL PROCEDURE SORTED BY IMPACTED TOOTH

Age	Tooth 13	Tooth 23	Both Teeth 13 and 23	Total	%
unknown	1	2		3	1.5
0-11	1	3		4	2.0
12-16	49	51	49	149	75.5
17-19	7	10	6	23	11.6
Over 20	7	7	4	18	9.4
TOTAL	65	73	59	197	100.0

78% of patients were less than 17 years old and 90% were less than 20 years old. An interesting fact was the scarcity of patients less than 12 years old (2%) which differs markedly from Ohman & Ohman (1980) who observed 17% in this age group. These findings correlate more closely with those of Buchanan (1984) who operated on 4% of cases involving patients below the age of 12, 76% between 12 and 15 years, 14% in the 16 to 18 age bracket and 6% older than 18 years.

Further aspects of the significance of the patient's age are explored as part of the sections which follow.

The table below shows the distribution of procedure by age group.

TABLE 13: INITIAL PROCEDURE BY AGE GROUP

Age Group	PROCEDURE									
Age	Exposure		Exposure with packing		Bonding		Bonding with exposure & packing		TOTAL No. of Teeth	
	No.	% of age group	No.	% of age group	No.	% of age group	No.	% of age group	No.	% of Total
10-16	8	4.0	29	15.0	116	61.0	38	20.0	191	78.0
17-19	1	3.5	2	7.0	20	69.0	6	20.5	29	11.8
20-23	-	-	-	-	9	41.0	13	59.0	22	9.0
unknown	-		-		2	66.7	1	33.3	3	1.2
TOTAL	9	3.7	31	12.6	147	60.0	58	23.7	245	100.0

The age groups have been combined to allow a more direct comparison with papers previously presented in the literature review.

The following patients required subsequent procedures:

TABLE 14: SECOND PROCEDURE BY AGE GROUP

Age Group	PROCEDURE							
	Exposure or exposure with packing		Bonding or bonding with exposure & packing		Extraction		TOTAL	
	No.	% of age group	No.	% of age group	No.	% of age group	No.	% of Total
10-16	15	60.0	6	24.0	4	16.0	25	71.4
17-19	7	87.5	1	12.5	-		8	20.0
20-33	2	66.7	-		1	33.3	3	8.6
TOTAL	24	66.7	7	19.4	5	13.9	36	100.0

Only two teeth required third procedures. One was a patient aged 22 years and the other a patient aged 26 years.

The number of teeth requiring a second procedure increased significantly in patients over the age of 16 years. Of teeth exposed (with or without packing) in the 10 to 16 year old age group, 4 (10.8%) required subsequent treatment (all received a bonding procedure) while the percentage requiring a second procedure jumped to 33% (1 in number) in the 17 to 19 year group.

These results were mirrored in the instances which recieved bonding only as a first procedure - 18.1% (21 number) in the under 17 age group required subsequent treatment (4 were extracted, 2 rebonded and 15 received some form of exposure), while the percentage retreated jumped to 35.0% (7 number) in the 17 to 19 age group, and 33.3% (3 number) in the 20 to 33 year old group.

The only patient to require subsequent treatment after receiving bonding together with exposure and packing as an initial procedure was a 33 year old who had the tooth extracted.

Further details of the second and third procedures are discussed below:

4.7 OPERATOR VARIATION

Of the 197 patients, 163 were operated on by the author, 13.5% (22 patients) of which required a subsequent procedure. Of the 34 patients treated by other operators, 38.3% (13 patients) needed a second procedure.

These figures probably reflect the author's greater familiarity with the techniques used.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 INCIDENCE, POSITION AND OTHER FACTORS INFLUENCING IMPACTION OF MAXILLARY CANINES

The incidence of bilateral impactions (24.4%), and the slight variation of impacted right (47%) to left (52%) teeth is in agreement with the presented literature. A similar agreement was found with the 70.6% of impacted maxillary canine teeth being palatally placed, 5.7% being in the line of the arch and 13.9% buccally/labially impacted. The incidence of impacted canines relating to small (5.5%), peg-shaped (10.0%) or absent lateral incisors (7.0%) was also in agreement with those reports which discuss this relation.

5.2 PROCEDURE

5.2.1 EXPOSURE TECHNIQUES

The initial decision to either bond or expose was primarily made according to the relation of the impacted tooth to the surface tissues. If the surface tissues could either be removed or repositioned leaving the tooth uncovered or if the superficial tissues could be removed or repositioned and, by the insertion of a pack, could be prevented from re-covering the tooth, then these procedures were undertaken. As the results indicate, this decision was made most successfully in patients up to the age of 16 years (only 10.8% required further work compared with 33% in older patients). These results confirm the work of Buchanan (1967) who suggested that the exposure techniques produce

best results if carried out within 2 years of the normal age of eruption.

When a bonding technique was chosen, the same criteria were used to decide whether exposure and packing of the tooth was suitable, however in these cases the age of the patient was not influential in the decision. The high success rate of the bonding with exposure and packing procedure (only 1.4% required follow-up surgery) would seem to reflect both the superficial positioning of the tooth (allowing easier orthodontic repositioning) and the removal of overlying obstructions (bony and soft tissues) which may allow a freer path for the tooth to move along.

5.2.2 BONDING TECHNIQUES

The principal aim of the research presented in this treatise was to assess the bonding technique developed in the Department of Oral Surgery at the University of Sydney. The results indicate that of the 218 teeth that had the mesh-chain appliance bonded to their surface, only 1.0% (2 teeth) required rebonding as a second procedure. All remaining teeth had the mesh-chain appliance either removed by the orthodontist on emergence of the tooth into the mouth, or had the appliance still in place at the termination of treatment by either extraction (2.8% or 6 teeth) or transplantation (0.5% or 1 tooth). It should be noted that in one of the 2 cases requiring rebonding, the gold chain had fractured at the welded link, the mesh remaining bonded to the tooth, this should therefore be considered a failure of the appliance rather than of the bonding technique.

Based on these results the author feels that the acid-etched bonding

technique is an effective means of treating impacted maxillary canines.

The University of Sydney technique used in this treatise is differs slightly from the technique of Hunt (1977) upon which it is based. The differences are -

(a) No use of pumice to prepare the tooth surface.

(b) Etching with 50% phosphoric acid for one minute (Hunt used 30% for one and one half minutes).

(c) Exposing and packing of selected teeth as the first surgical procedure rather than replacing and suturing of soft tissue in all cases.

(d) The appliance constructed is smaller and more flexible than the gauze backed stainless steel band material with welded orthodontic appliances attached.

These differences reflect a streamlining of the technique. Using the University of Sydney mesh-chain results in much less bulk needing to be drawn through the soft tissues. The mesh-chain can be adapted to any coronal surface allowing a more selective placement near the tip for more effective orthodontic traction.

Placing the mesh-chain near the tip of the tooth reduces the extent of exposure necessary for sufficient access, thereby reducing the risk of damage to the adjacent teeth roots and leaving the attachment of the dental follicle intact at the cervical margin.

The technique of acid etched bonding to impacted maxillary canines requires scrupulous attention to the maintenance of a completely dry field and adherence to the manufacturer's instructions with regard to the mixing and placement of the bonding material and appliance. To this end the use of a local anaesthetic solution containing adrenalin, a suitable suction-retraction device and warm dry air from a hair dryer were found to be highly effective in this study.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 CONCLUSIONS

The directly bonded mesh chain satisfies the requirements of a suitable method for attachment to impacted maxillary canines suggested by Helmore (1967).

a) it should be simple and easily applied without the necessity for destructive surgery:

b) it should cause no damage to the tooth being treated:

c) it should provide a positive attachment to the tooth without irritation to the surrounding tissues.

The techhnique achieves these requirements and has several major advantages over those currently in use.

1. The mesh chain may be modified for bonding to almost any position on the crown of an unerupted canine tooth, including the incisional edges. This allows the orthodontist to select the area of the tooth most beneficial to traction, thus increasing the efficiency of his procedures.

2. The whole procedure is done as a single, simple operation thus reducing stress to the patient and allowing the orthodontist to begin traction immediately.

3. The replaced flap reduces post-operative discomfort and protects the adjacent tissues.

4. Eruption of the tooth is through keratinized epithelium promoting normal gingival attachment, even for labially displaced teeth.

5. The adjacent teeth and tissues are not traumatized as is possible when ligating with wires around the cervical margin, or when cementing caps or bands to the tooth.

6. There is no damage to the crown of the tooth by pins or holes, or stripping of the cervical attachment of the dental follicle with subsequent cemental resorption which may follow cervical ligation with wire.

7. All components are easily manufactured or are readily available and are less bulky than commercially prepared brackets. This reduces the volume being pulled through the soft tissues.

Areas of possible failure are either in the manufacturing of the attachment by poor or insufficient welds, or by poor isolation and manipulation during etching and holding of the mesh during bonding. By carefully preparing the mesh-chain and meticulously following the correct procedures, these failures can be avoided.

6.2 SUMMARY

A significant proportion of orthodontic practice involves the management of impacted teeth that require surgical procedures to aid in their successful realignment.

A technique for direct bonding to the crown is a simple, one operation procedure which does not damage the tooth or adjacent tissues.

The most beneficial application of force to any preselected aspect of the crown to reduce traction time can be achieved by optimal siting of the attachment.

If carried out correctly, there is little likelihood of failure.

APPENDIX

EXTRACT FROM MANUFACTURER'S INSTRUCTION

for use of

CAULK SOLO-TACH

orthodontic bonding agent for direct placement methods

1. Clean and polish teeth with a non-fluoride prophylaxis material. Rinse teeth with water (use evacuator to remove water) and thoroughly dry with air from an air syringe.

   A dry field must be maintained throughout the procedure. This may be accomplished through insertion of Dri-Angles* (triangular blotters usually placed in cheek over Stensen's Duct), cheek retractors, and a saliva evacuation system.

2. Condition appropriate enamel surfaces of teeth with Caulk Tooth Conditioner (contains free phosphoric acid - 50% by weight). Saturate a small cotton pledget with Tooth Conditioner and apply using a continuous, slow and gentle wiping action across the enamel for 60 seconds.

   Do not use pressure. The exact conditioning time will vary depending on how many teeth are being done simultaneously. The last tooth in the sequence should be exposed to the conditioning solution for 60 seconds.

After conditioning and while aspirating, rinse the teeth with a forceful spray of water (that does not contain mouthwash); then dry thoroughly with air from an air syringe. If surface has been properly conditioned, it will have a dull (whitish) satiny appearance.

5. Avoid any possibility of saliva contamination by keeping entire arch well isolated. Saliva on the tooth surface will interfere with bonding of SOLO-TACH to conditioned surfaces. Also, do not wipe away Tooth Conditioner with a cotton roll or other absorbent material.

   If contamination occurs, dry the tooth surface with air and recondition for 10 seconds followed by rinsing and drying as in Step 4.

6. Prior to dispensing pastes, wipe any initial condensation from cooled mixing slab using a clean paper towel. As tooth drying process nears completion, an assistant should dispense equal portions of activated catalyst and base pastes onto a cooled mixing slab. To avoid cross contamination of base and catalyst pastes, use opposite ends of spatula when dispensing from each jar. Carefully clean the spatula after mixing to avoid future cross contamination.

   Spatulate the pastes together for 10-15 seconds to make a homogeneous mixture. Without delay, apply mixed SOLO-TACH to contacting surface (base) of bracket. Place bracket in position with normal pressure and, while paste is still fluid, lap excess over bracket flange using a suitable instrument.

   NOTE: Placement technic must be completed within 1 to 1 1/2 minutes from start of mix.

During bracket placement, patient should be in appropriate supine position to minimize possibility of brackets drifting prior to setting of SOLO-TACH.

7. After positioning, the bracket must remain undisturbed for 3 1/2 minutes from the start of the mix for the SOLO-TACH to completely harden. A small residual portion of the mix may be placed on the instrument table cover to check for setting time.

8. Following hardening, excess material should be removed from interproximal and other areas.

9. Wires may be placed after attachments have been examined and excess material removed (approximately 5 minutes after last attachment has been bonded).

10. Initial strap-up should be performed with a light flexible wires. Any wire can be used after 24 hours.

BIBLIOGRAPHY

ADAMSON, KT. The problem of impacted teeth in orthodontics. Dent J Aust 1952 : 24:143-154.

ADELMAN, AB. Surgical and orthodontic management of ectopic teeth. Dent Digest 1969 : 75:13-19.

AITASALO, K., LEHTINEN, R. & OKSALA, E. An orthopantomographic study of prevalence of impacted teeth. Int J Oral Surg 1972 : 1:117-120.

ALTONEN, M. & MYLLARNIEMI, S. Results of surgical exposure of impacted cuspids and bicuspids in relation to patients' somatic and dental maturation. Int J Oral Surg 1976 : 5: 180-186.

ANDREASEN, GF. A review of the aproaches to treatment of impacted maxillary cuspids. Oral Surg 1971 : 31:4:479-484.

ARCHER, WH. Oral and Maxillofacial Surgery. Fifth edition 1975. WB Saunders Co. p.338-364.

AZAZ, B. & SHTEYER, A. Resorption of the crown in impacted maxillary canine. Int J Oral Surg 1978 : 7 : 167-171.

BASS. TB. Observations on the misplaced upper canine tooth. Dent Practit 1967 : 18:1:25-32.

BECKER, A., KOHAVI, D. & ZILBERMAN, Y. Periodontal status following the alignment of palatally impacted canine teeth. Am J Orthod 1983 : 84:4:332-336.

BECKER, A. & ZILBERMAN, Y. The palatally impacted canine : a new approach to treatment. Am J Orthod 1978: 74:4:422-429.

BECKER, A., ZILBERMAN, Y. & TSUR, B. Root length of lateral incisors adjacent to palatally-displaced maxillary cuspids. The Angle Orthodontist 1984 54:3:218-225.

BECKER, A., SMITH, P. & BEHAR, R. The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids. The Angle Orthodontist 1981 51:1:24-29.

BECKER, A. Etiology of maxillary canine impactions. Letter to the Editor. Am J Orthod. 1984 : 86:5:437-438.

BISHARA, SE., KOMMER, DD., McNEIL, MH., MONTAGANO, LN., OESTERLE, LJ. & YOUNGQUIST, HW. Management of impacted canines. Am J Orthod 1976 69:4:371-387.

BLUM, T. Malposed teeth: Their classification, pathology and treatment. Int J Orthod 1923 : 9:122-137.

BOYD, RL. Clinical assessment of injuries in orthodontic movement of impacted teeth. J Methods of attachment. Am J Orthod 1982 : 82:6:478-486.

BOYD, RL. Clinical assessment of injuries in orthodontic movement of impacted teeth. II Surgical recommendations. Am J Orthod 1984 : 86:5:407-418.

BROADBENT, BH. Ontogenic development of occlusion. Angle Orthod 1941 : 11:223-241.

BROWN, ID. & MATTHEWS, RW. Apical resorption of a maxillary lateral incisor from a misplaced canine in 17 year old. A case report. Brit J Orthod 1981 : 8:3-5.

BUCHANAN, G. Surgical intervention as an aid to orthodontics. Annals of Aust Coll Dent Surg 1967 : 1:70-77.

BUONOCORE, MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res Dec 1955 : 34 : 849-853.

BUONOCORE, MG. Adhesives in the prevention of caries. JADA Oct 1973 87: 1000-1005.

CLARK, CA. A method of ascertaining the relative position of unerupted teeth by means of film radiographs. Proc Roy Soc Med (sec Odont) 1910 : 3:87-90.

CLARK, D. The management of impacted canines : free physiologic eruption. JADA 1971 : 82:836-840.

COATOAM, GW., BEHRENTS, RG. & BISSADA, NF. The width of keratinized gingiva during orthodontic treatment : its significance and impact on periodontal status. J Period 1981:52:6:307-313.

COHEN, B. A study of the periodontal epithelium. Brit Dent J 1962 : 112:2:55-68.

CRANIN, AN. & CRANIN, SL. Aiding eruption of maxillary cuspids. Dental Radiography & Photography 1968 : 41:2:27-34.

DACHI, SF. & HOWELL, FV. A survey of 3874 routine full-mouth radiographs. II A study of impacted teeth. Oral Surg 1961 : 14:10:1165-1169.

DEWEL, BF. The upper cuspid : its development and impaction. Angle Orthod 1949 : 19:79-90.

DI BIASE. Mucous membrane and delayed eruption. Dent Practit 1971 : 21:7:241-250.

DI SALVO, NA. Evaluation of unerupted teeth : orthodontic viewpoint. JADA 1971 : 82:829-835.

ELIASSON, S., LAFTMAN, AC. & STRINDBERG, L. Autotransplanted teeth with early-stage endodontic treatment: A radiographic evaluation. Oral Surg 1988 : 65:5:598-603.

FASTLICHT, S. Treatment of impacted canines. Am J Orthod 1954 : 40:12:891-905.

FOURNIER, A.. TURCOTTE, J. & BERNARD, C. Orthodontic considerations in the treatment of maxillary impacted canine. Am J Orthod 1982 : 81:3:236-239.

GENSIOR, AM. & STRAUSS, RE. The direct bonding technique applied to the management of the maxillary impacted canine. JADA 1974 : 89:1332-1337.

GOLDSTEIN, AR. & SCHPERO, M. Retained ligature wire and periodontal health. Report of a case. Am J Orthod 1984 : 86:4:315-318.

GRABER, TM. Orthodontics Principles and Practice. Third Edition 1972. WB Saunders Co. p.286.

GWINNETT, AJ. Morphology of the interface between adhesive resins and treated human enamel fissures as seen by scanning electron microscopy. Arch Oral Biol Feb 1971 : 16:237-238.

HAGERSTROM, AL. & BJORLIN, G. Surgical orthodontic treatment of impacted canines in the upper jaw. (Summary) Sven Tandlak Tidskr 1967 : 60:3:129-133.

HEANEY, TG. & ATHERTON, JD. Periodontal problems associated with the surgical exposure of unerupted teeth. Brit J Orthod 1976 : 3:2:79-85.

HELMORE, FD. Surgical aid to eruption for orthodontic treatment. Aust Dent J 1967 : 12:4:372-378.

VAN DER HEYDT, K. The surgical uncovering and orthodontic positioning of unerupted maxillary canines. Am J Orthod 1975 : 68:3:256-276.

HITCHIN, AD. The impacted maxillary canine. Brit Dent J 1956 : 100:1:1-12.

HOVELL, JH. Some surgical procedures related to orthodontic treatment. Dent Practit 1958 : 9:21-30.

HOWARD, RD. The unerupted buccally displaced maxillary canine. Surgico-orthodontic management. Brit Dent J 1970 : 129:9-16.

HOWARD, RD. The displaced maxillary canine: Positional variations associated with incisor resorption. Trans Brit Soc Study Orthod 1971 : 149-157.

HOWARD, RD. Impacted tooth position : Unexpected improvements. Brit J Orthod 1978 : 5:87-92.

HOWE, GL. Minor Oral Surgery Second Edition 1971 Bristol : John Wright & Sons Ltd. p.126-133.

HUNTER, SB. Treatment of the unerupted maxillary canine Part I. Preliminary considerations and surgical methods. Brit Dent J 1983 : 154:294-296.

HUNTER , SB. The radiographic assessment of the unerupted maxillary canine. Brit Dent J 1981 : 150:151-155.

JACOBY, H. The etiology of maxillary canine impactions. Am J Orthod 1983 : 84:2:125-132.

JOHNSTON, WD. Treatment of palatally impacted canine teeth. Am J Orthod 1969 : 56:6:589-596.

JONES, JH. & MASON, DK. Oral Manifestations of Systemic Disease. 1980 WB Saunders. p.215-220.

KETTLE, MA. Treatment of the unerupted maxillary canine. Trans Brit Soc Study Orthod 1957 : 74-84.

KETTLE, MA. Treatment of the unerupted maxillary canine. Dent Practit 1958 : 8:8:245-255.

KILLEY, HC., SEWARD, GR. & KAY, LW. An Outline of Oral Surgery - Part I 1971 Bristol: John Wright & Sons Ltd. p.37.

KINCAID, LC. Flap design for exposing a labially impacted canine. J Oral Surg. 1976 : 34:270-271.

KOHAVI, D., BECKER, A. & ZILBERMAN, Y. Surgical exposure, orthodontic movement, and final tooth position as factors in periodontal breakdown of treated palatally impacted canines. Am J Orthod 1984 : 85:1:72-77.

KOHAVI, D., ZILBERMAN, Y. & BECKER A. Peridontal status following the alignment of buccally ectopic maxillary canine teeth. Am J. Orthod 1984 : 85:1:78-82.

KRAMER, RM. & WILLIAMS, AC. The incidence of impacted teeth. A survey at Harlem Hospital. Oral Surg 1970 : 29:2:237-241.

KRUGER, D. & WORTHINGTON, A. Oral Surgery in Dental Practice. 1981. Quintessence Publishing Co Inc. p.224,265-266.

LASWELL, HR.,WELK, DA. & REGENOS, JW. Attachment of resin restorations to acid pretreated enamel. JADA March 1971 : 82:558-563.

LEE, BD., PHILLIPS, RW. & SWARTZ, ML. The influence of phosphoric acid etching on retention of acrylic resin to bovine enamel. JADA June 1971 : 82:1381-1386.

LESLIE, HE. A new improved method of treatment of impacted or unerupted teeth. Am J Orthod 1955 : 41:583-593.

LEVIN, MP. & D'AMICO, RA. Flap design in exposing unerupted teeth. Am J Orthod 1974 : 65:4:419-422.

LEVINE, B. & SKOPE, L. Direct bonding of unerupted teeth for orthodontic movement. JADA 1979 : 98:55-57.

LEWIS, PD. Preorthodontic surgery in the treatment of impacted canines. Am J Orthod 1971 : 60:4:382-397.

MOLONEY, F., TIDEMAN, H. & STOELINGA, PJW. The palatally impacted cuspid tooth: a new surgical approach to treatment. Aust Dent J 1985 : 30:1:37-46.

McKAY, C. The unerupted maxillary canine. An assessment of the role of surgery in 2,500 treated cases. Brit Dent J 1978 : 145:207-210.

MILLER, BH. The influence of congenitally missing teeth on the eruption of the upper canine. Trans Brit Soc Study Orthod 1963 : 17-24.

MOSS, JP. An orthodontic approach to surgical problems. Am J Orthod 1975 : 68:4:363-390.

MOSS, JP. The unerupted canine. Trans Brit Soc Study Orthod 1971 : 137-143.

MOUSER, PG. A technique for direct bonding of unerupted teeth as an aid to orthodontics. Aust Dent J 1980 : 25:3:121-124.

NIELSEN, IL., PRYDSO, U. & WINKLER, T. Direct bonding on impacted teeth. Am J Orthod 1975 : 68:6:666-670.

NORDENRAM, A. & STROMBERG, C. Positional variations of the impacted upper canine. Oral Surg 1966 : 22:6:711-714.

NORTON, LA. Treatment of impacted canines. J Clin Orthod 1971:5:8:454-455.

OHMAN, I. & OHMAN A. The eruption tendency and changes of direction of impacted teeth following surgical exposure. Oral Surg 1980 : 49:5:383-389.

OSTROFSKY, MK. Localization of impacted canines with Status - X radiography. Oral Surg 1976 : 42:529-533.

PORTER, WJ. & RIDER, EA. A method of anchorage for orthodontic movement of unerupted teeth. J Oral Surgery 1974 : 32:513-515.

POWELL, KR. An in-vitro study of the penetrating and sealing properties of BIS-GMA resin pit and fissure coatings. MDS Thesis Univ of Sydney 1975.

PRESCOTT, M. & GOLDBERG, M. Controlled eruption of impacted teeth with threaded pins. J Oral Surg 1969 27. 615-618.

RATCLIFFE, PH. An assessment of the treatment plan alternatives for the unerupted and impacted maxillary canine. MDS Thesis Univ of Sydney 1977.

RAYNE, J. The unerupted maxillary canine. Dent Practit 1969 : 19:6:194-204.

RETIEF, DH. Effect of conditioning the enamel surface with phosphoric acid. J Dent Res 1973:52:333-341.

REVELL, JH. Surgical orthodontics. New methods to stimulate and direct eruption. Int J Orthod 1964 : 2:5-20.

REYNOLDS, IR. & von FRAUNHOFER, JA. Direct bonding of orthodontic attachments to teeth : the relation of adhesive bond strength to gauze mesh size. Brit J Orthod 1976 : 3:2:91-95.

ROHLIN, M. & RUNDQUIST, L. Apical root anatomy of impacted maxillary canines. A clinical and radiographic study. Oral Surg 1984 : 58:2:141-147.

ROHRER, A. Displaced and impacted canines. A radiographic research. Int J Orthod 1929 : 15:1003-1020.

SASAKURA, H., YOSHIDA, T., MURAYAMA, S., HANADA, K. & NAKAJIMA, T. Root resorption of upper permanent incisor caused by impacted canine. An analysis of 23 cases. Int J Oral Surg 1984 : 13:299-306.

SHAFER, WG., HINE, MK. & LEVY, BM. A Textbook of Oral Pathology. Third Edition 1974. WB Saunders Co. Chapter 1 p.2-75.

SHAPIRA, Y. & KUFTINEC, MM. Treatment of impacted cuspids. The hazard lasso. Angle Orthod 1981 : 51:3:203-207.

SMITH, DC. A milestone in dentistry. Oper dent 1982 : 7:1:14-25.

SMYTH, J. The periodontal status of the orthodontically treated palatally impacted canine tooth. A pilot study. MDS Thesis 1981 Univ of Sydney.

STROCK, MS. A new approach to the unerupted tooth by surgery and orthodontics. Am J Orthod 1938 : 24:626-634.

TAKAHAMA, Y. & AIYAMA, Y. Maxillary canine impaction as a possible microform of cleft lip and palate. European J Orthod 1982 : 4:275-277.

THILANDER, H., THILANDER, B. & PERSSON, G. Treatment of impacted teeth by surgical exposure. A survey study. Sven Tandlak Tidskr 1973 : 66:519-525.

THILANDER, B. & JAKOBSSON, SO. Local factors in impaction of maxillary canines. Acta Odont Scand 1968 : 26:145-168.

THILANDER, B. & MYRBERG, N. The prevalence of malocclusion in Swedish school children. Scand J Dent Res 1973 : 81:12-20.

TURK, MH. & KATZENELL J. Panoramic localization. Oral Surg 1970 : 29:212-215.

TURNER, EP. Dental manifestations of systemic disease. In: Oral Manifestations of Systemic Disease. Eds. Jones JH., Mason DK. 1980. WB Saunders Co.

VANARSDALL, RL. & CORN, H. Soft tissue management of labially positioned unerupted teeth. Am J Orthod 1977 : 72:1:53-64.

WEISS, B., JACOBS, BJ. & RAFEL, SS. A surgico-orthodontic approach to the treatment of unerupted teeth. Angle Orthod 1953 : 23:4:201-211.

WHITLOCK, RIH. & HAMILTON, W. The impacted maxillary canine. Dental News 1968 : 5:9:1-3.

WILLIAMS, BH. Diagnosis and prevention of maxillary cuspid impactions. The Angle Orthodontist 1981 : 51:1:30-40.

WISTH, PJ., NORDERVAL, K. & BOE, OE. Comparison of two surgical methods in combined surgical-orthodontic correction of impacted maxillary canines. Acta Odont Scand 1976 : 34:53-57.

WISTH, PJ., NORDERVAL, K. & BOE, OE. Periodontal status of orthodontically treated impacted maxillary canines. Angle Orthod 1976 : 46:69-76.

WRAITH, K. Methods of repositioning the misplaced canine. Dent Practit 1969 : 19:11:387-393.

ZIEGLER, TF. A modified technique for ligating impacted canines. Am J Orthod 1977 : 72:6:665-670.

DENTISTRY LIBRARY
UNIVERSITY OF SYDNEY