SOME COMPARISONS OF SLOW AND RAPID MAXILLARY EXPANSION

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INTRODUCTION

The controversy that initiated my interest in the differences between "slow" and "rapid" maxillary expansion can be found in Sim (1977, page 287) who claims that the advantages of the slow expansion method include, better control of the changes in palatal anatomy, less discomfort, and less need for anatomic changes at the sites of other sutures. Later on page 287 he states that "in cases in which rapid expansion is used, the dentist finds that retention appliances must be used for the same length of time that it takes the slow expansion method to achieve the same added dimension to the palatal arch and no time is really saved.

This seems to assume that the differences in treatment time was the major advantage of rapid expansion and that other differences in treatment goal, and methods of achieving them, were similar to slow expansion. Finding this assumption unacceptable created the desire to clarify, in a clinical situation, the indicators for, and uses of, "rapid" and "slow" expansion techniques.

The writings of numerous authors on expansion techniques tends to be polarized by R.M. Ricketts' use of the quad-helix appliance and his reasoning (Ricketts 1973) for not having used rapid maxillary expansion for the last three years. The articles of A.J. Haas represent the advocates of rapid expansion. The study of the reports in the literature on the two techniques form the basis for this treatise and for comparisons of the effects of "slow" versus "rapid" maxillary expansion.

An hypothesis on which to base my study is the comment by Ricketts (1979) that "It appears that after six months the effects of the jackscrew
and quad-helix are similar in extent of final nasal floor involvement''.

The resultant hypothesis thus becomes: The effects of "rapid" versus "slow" expansion are very similar in the basal area of the maxillary arch. This hypothesis then has to be considered at different ages. Thus, the two principle variables to be considered will be the rate of expansion compared to the age of the patient. A third important consideration is the severity of the condition and the need for accurate diagnosis of the skeletal and dental components of the condition when deciding between the use of rapid or slow expansion techniques.
CHAPTER 1

CLASSIFICATION DIAGNOSIS AND ETIOLOGY

1.1 Classification and Etiology

1.1.1 Definitions

The single common indicator for the need for maxillary expansion is a posterior lingual crossbite.

Crossbite: As a definition, Faber (1981) suggests a crossbite is an abnormal bucco-lingual relationship of the teeth and apparent dental relationships may mask underlying skeletal discrepancies.

Lingual: Where the buccal cusps of some of the upper posterior teeth occlude lingually to the buccal cusps of the lower posterior teeth Moyers (1973, page 313) suggests that when one or more of the maxillary teeth are in crossbite towards the midline it is termed "lingual crossbite". This and the situation where the upper molar occludes lingually to the lingual cusp of the lower teeth, or complete lingual crossbite, are the cases where maxillary expansion is considered as a means of treatment.

For completeness of classification, there is also a buccal crossbite where the lingual cusp of the upper molar or premolar occludes buccally to the buccal cusp of the lower molar. Thus each is named according to the buccolingual positions of the upper posterior teeth as they relate in functional occlusion with their opposing lower teeth. Each can be expressed functionally only on one side of the arch qualifying it as unilateral, or on both sides which makes it bilateral (Fig. 1.1).
Fig. 1.1  Classification of Posterior Crossbites

Sim (1977) p. 278

Two distinct types of lingual crossbite are emphasised, the causes of which are determined by whether the mandible shifts perceptibly as the child closes into occlusion. Sim (1977, page 275) "A posterior crossbite is considered functional, (also called a convenience pattern or habitual pattern
or habitual pattern of occlusion), if a mandibular shift is present during the final two to three millimeters of closure. If the child's mandible does not shift as he is closing into his final occlusion Sim describes the posterior lingual crossbite as skeletal (genetic or anatomic). Thus the clinical unilateral functional crossbite is usually a mild skeletal bilateral crossbite. Sim (page 277) continues that the original functional condition may lead to alveolar changes caused by the occlusal forces involved which may eliminate the functional component. This however, remains a functional condition not a skeletal one. Also there is general agreement according to Sim that crossbites are genetic, or skeletal, in origin and the functional component is superimposed on this.

Mathews (1966) agreeing with the two general categories describes the functional group as, when the jaw deviates from the midline in the final few millimeters of closure to produce a unilateral crossbite. It is actually bilateral in nature, since the width of the maxillary arch is insufficient to encompass the mandibular dental arch. This usually has its beginnings when the maxillary canines erupt without sufficient intercanine width to clear the lower canines on closure. The patient learns to deviate to a bite of convenience and this relationship is perpetuated as the other teeth erupt.

Haas (1965) includes the need to differentiate between a real and relative deficiency. A relative maxillary deficiency is when the maxilla is of expected size when compared to the upper face and cranium, but the mandible is too large relative to these structures. The discrepancy is usually in width in ClI and ClII cases, but in ClIII cases the discrepancy includes width and length. The real maxillary deficiency is characterised by compression of the maxilla with constriction of the buccal segments, the teeth may be upright but they are usually inclined buccally. Haas goes on
that the labial and buccal musculature rarely permits further tipping of the teeth and the tongue rarely tolerates the confining aspects of the contracted mandibular arch. Haas therefore suggests correction of the denture base width, rather than the dental arch width is required. He recommends the use of rapid maxillary expansion to increase the dimensions of the maxillary arch as his maximum anchorage appliance combined with the rapid rate of expansion will produce basal bone expansion, rather than the slower-acting less rigid appliances which he believes leads to dental tipping and orthodontic and alveolar changes.

1.1.2 Classification

Moyers (1973, page 532) in discussing the treatment of dentoalveolar constriction stresses the importance of determining how much of the condition is due to dentoalveolar constriction and how much to the muscular adaptive positioning of the mandible. He classifies crossbites into:

Dental: only tipping of teeth is involved, it is localised to alveolar bone and does not affect the basal bone or midline.

Muscular: This, Moyers describes as a neuromuscular adjustment to tooth interference. It is similar to the above, but the teeth are not tipped in the alveolus. In the dental crossbite teeth must be moved, whereas in the muscular crossbite occlusal equilibration permitting changes in muscular reflexes governing muscular positioning may be sufficient.

Osseous: This includes the gross disharmonies of the facial skeleton, asymmetries, and lack of agreement in the widths of the dental arches. It is usually a bilateral constriction, but the muscles may shift the
mandible to one side to acquire sufficient occlusal contact for mastication just before the teeth make contact. If the deviation increases throughout opening the fault is likely to be asymmetrical bone growth, ankylosis of the joint, or tumours and arthritic conditions could also be considered.

Moyers (1973, page 539) considers the midlines and if they are aligned then it is mostly skeletal; if they are not together some functional adaptation is occurring. It is his suggestion then, to locate the interferences when the midlines are aligned, remove these interferences, particularly in the deciduous dentition stage, and this may correct minor problems making further treatment unnecessary. When considering the unilateral functional crossbite, the correction required is actually bilateral expansion, whereas in the skeletal problem with a true unilateral crossbite, appliance design is a much more difficult problem as most commonly used appliances have a bilateral reciprocal anchorage concept built into their design.

Kutin and Hawes (1969) used Moyers' classification. Of their 80 recorded cases, 23 showed obvious skeletal discrepancies, bilateral crossbites with matching midlines. 34 of the remaining 57 had midline discrepancies and would fit Moyers' muscular (functional) category. However, many of them could also be classified as osseous discrepancies on the basis of aligning midlines where the crossbites were still evident and almost always bilateral. On the other hand 21 cases showed unilateral crossbite with midlines aligned indicating true unilateral crossbites. There are, however other factors, to be considered with the midlines agreeing than just mandibular displacement.

Factors affecting the relationship of incisor midlines includes, arch
asymmetry, and symmetry, sequence of eruption or tooth loss, and the discrepancy of tooth size either within the arch or between arches. In other words the midlines between the arches is not an absolute indicator of the lateral position of the mandible with respect of the maxilla and must be checked against facial midlines. In the study by Kutin and Hawes only early crossbites have been considered and it is accepted that other factors will have greater significance in an older age group.

1.1.3 Etiology

As expressed in the classification, the main cause of posterior crossbite is a skeletal or genetic discrepancy in the size of the maxilla when compared to the mandible. Kutin and Hawes (1969) listed a number of additional possible factors.

Prolonged retention or premature loss of deciduous teeth. Clinch (1966) is quoted as saying "anatomical shapes of teeth guide subsequent teeth during eruption and thus aberrations in tooth anatomy or eruption sequence may cause crossbites to develop.

Thumbsucking, mouthbreathing, finger and tongue habits. Graber (1972) suggests that these factors contribute to creating a narrow maxillary arch. Graber felt that this particularly applies to active suckers where the sucking pressure applied by the buccinator muscle results in maxillary contraction aided by the fact that the tongue is being held in a lowered position by the thumb and thus offers little resistance to the contractile pressure. Melsen et al. (1979) found that it is the prolonged thumb suckers that are affected. They found that irreversible malocclusions are produced if sucking habits persist beyond the age of four. They also found a positive correlation between the frequency of crossbites and both pacifier sucking
and finger sucking, but that pacifier sucking had the stronger correlation. Infante (1976) from an epidemiologic study of finger habits related to malocclusion in preschool children concluded that, the relationship of finger sucking to posterior lingual crossbite, and CII molar relationships was significant. However, as the prevalence of finger sucking declined with increasing age, the prevalence of CIII molar relationship declined significantly whereas the prevalence of posterior lingual crossbite remained the same and this is not self correcting.

Subtelny (1980) suggests, that there is a strong clinical association between excessive nasopharyngeal blockage and the extent of naso-maxillary growth. Many cases had some degree of maxillary retrusion coincident to their mouthbreathing habit. The problem here is which comes first? Is the mouthbreathing habit the result of inadequate development of the naso-maxillary complex, or is the lack of nasomaxillary development the cause of mouthbreathing? It might be surmised that one of the factors relative to a potential for achieving optimal development of the nasomaxillary complex seems to revolve around the ability for sustaining nasal respiration.

Clefts of the secondary palate. Wood (1962) discussing the cleft conditions, felt that the palatal cleft, with or without a cleft of the lip, is usually accompanied by a severe crossbite. This may be a contractile effect of the scar tissue following surgery being superimposed on an already deficient maxilla. The presence of the scar tissue, depending on its extent, may impose limitations to orthodontic treatment.

1.2 Diagnosis

A problem list for evaluation of posterior lingual crossbite should include:
- The number and location of teeth involved.

- The presence or absence of a functional path of closure, and centric occlusion and centric relation discrepancies.

- Molar cusp relationships and the radiographic examination and evaluation of skeletal discrepancies.

- Study model evaluation of dental and skeletal discrepancies. This should involve an evaluation of the curve of Monson (Fig. 1.2). If the upper cast is placed on a flat plane, the lingual cusps of the maxillary teeth should contact that plane. If this is so, the upper teeth are inclined buccally, conversely if the lower buccal cusps contact the plane, the lower molars are inclined lingually. If they are also in crossbite then it is very probably a skeletal problem. However, if they are reversed or the teeth are obviously tipped abnormally, then it is probably a dental problem.

Bench et al. (1978) utilize the curve of Monson in diagnosis. Where the upper first molars and deciduous buccal segments are inclined medially, that is, demonstrate a reverse curve of Monson, it is desirable to expand the upper arch by means of an outward tipping of the buccal segments. The alveolar process is then bent or warped out into a more normal inclination. This then is ideal for the slow expansion procedures. This has to be distinguished from the true maxillary deficiency where the upper buccal segments have good axial inclination, but there is a generalized narrowness of the maxillary vault. Now the degree of skeletal discrepancy and the age of the patient become major factors in deciding between slow and rapid expansion procedures.

In his consideration of diagnosis of crossbites Buck (1970) used four orthodontic evaluations.
Fig. 1.2 A. Positive Curve of Monson  
B. Negative Curve of Monson

The skeletal evaluation: Is there a large bony discrepancy or mainly one of tooth position? He feels that fewer than 5% have a severe skeletal component.

The lower arch: Check for crowding; special attention should be given to the buccolingual position of the mandibular permanent molars. When assessing the lower arch keep in mind the concepts of arch length deficiency with age due to the uprighting of the anteriors and mesial
movement of molars. Also the intercanine width is relatively stable at nine years of age and any increase from this dimension has been shown to be relatively unstable.

The upper arch: This he assesses in much the same way as described earlier.

The significance of mandibular slides: After initial contact Faber (1981) expresses the possible difficulties encountered with pseudo ClIII's with functional shifts both anteroposteriorly and laterally. An apparent unilateral crossbite that is really bilateral may be further complicated by an anterior functional shift into an anterior crossbite. Without the anterior shift the crossbite may be only slight or even a true unilateral asymmetry.

1.3 Timing of Treatment

The single feature most often repeated in the literature is the desirability of early treatment of posterior crossbites. "The early correction of posterior crossbites requiring maxillary expansion has been advocated to redirect the maxillary teeth into more normal positions, eliminate untoward mandibular joint positions and mandibular closure patterns, and make beneficial dentoskeletal changes during growth periods involving a reduced treatment complexity and duration" (Bell, 1982). Ricketts (1979) describes the object of early treatment as the resolution of functional problems. The practical definition of a functional problem is anything that disturbs the growth, health, and function of the temporomandibular joint complex.
1.3.1 To Redirect the Developing Teeth into More Normal Positions

Barnes (1956) suggests the concept of movement or correction of the irregularity in the deciduous dentition, by moving the deciduous molars to the position they should occupy, will carry the crypts of their succedent permanent teeth with them. Carl Breitner (1940) studied the concept histologically and found that "... orthodontic movement of deciduous teeth produced migration of the underlying tooth germs. The direction in which the tooth germs move, corresponds to the direction taken by the roots of the adjacent erupted teeth". His histological evidence for indications of movement were, the narrowed width of the periodontal space indicated pressure, and the presence of giant cells in the adjoining thin layer of bone was an indication of resorption occurring; on the opposite side widening of the periodontal space and deposition of new bone lined with osteoblasts. The presence of resorption may also be manifested by osteoclasts and the serrated surface of the bone margins. Breitner's conclusions included: a tooth germ situated between the roots of the deciduous teeth will follow the movement of those roots. If situated in front of the roots it will be pushed in the direction the root moves, or if behind the root, in respect of its movement, will be pulled in the direction of the root movement.

Kutin and Hawes (1969) found that 77% of the patients had some form of posterior crossbite. It was not evident that the problems of crossbites improved with the eruption of permanent teeth. However, in cases with deciduous teeth in crossbite which were corrected, permanent teeth erupted into normal relationships. Thus they concluded treatment should be undertaken as early as possible.
1.3.2 Eliminate Untoward Temporomandibular Joint Positions

Myers et al. (1980) did a study to determine whether functional posterior crossbites in children influence the position of the mandibular condyle in the glenoid fossa and assess the effect of crossbite correction on condylar position. They demonstrated that a functional posterior crossbite in a child is associated with compression of the condyle in the fossa on the crossbite side, and extension of the condyle in the fossa on the opposite side. Correction of the crossbite eliminated the asymmetric positioning of the condyle in the fossa between the two sides.

Bench et al. (1978) in their radiographic evaluation suggest that the radiographs reveal that as the mandible shunts to one side, the condyle is typically brought down on the eminence on one side and is either ideally seated or distally positioned on the other side. The opposite side to the shift acts in a transitory manner, while the shifting side condyle is brought into apposition with the greatest height of the eminence. The resultant growth changes are that where the transitory condyle may experience normal growth and development, the opposite side condyle will commonly exhibit restricted growth on its anterosuperior surface and increased growth on its posteriosuperior surface. Long term growth effects will demonstrate a cant in the occlusal plane, abnormal ramal heights, alveolar process heights, and abnormal chin position.

Numerous authors support the concept of early treatment. Clifford (1971) says that "advice against early treatment is not only incorrect but constitutes gross neglect". Davis (1969) considers that the type of appliance used may not be as important as early treatment itself. His reasons include that if the primary dentition is in crossbite invariably the eruption of permanent teeth will follow in the same pattern. Due to loss of maxillary
bone development, muscle imbalance will occur due to the patient attempting to accommodate to the crossbite. Wood (1962) and Faber (1981) include temporomandibular joint disturbances in their indications for early treatment of posterior crossbites, with support for the concept of promotion of joint disturbances and possible retardation of condylar growth the longer they are left untreated.

1.3.3 Abnormal Mandibular Closure Patterns and Beneficial Dento-skeletal Changes During Growth

Barnes (1956) following on from his comments on redirecting tooth movements suggests that the earlier treatment has an improved potential for muscle retraining of mandibular closure patterns and thus the direction of future growth. Harvold (1963) when considering the biological aspects of orthodontic treatment, supported the concept that prevention is better than cure. While discussing the apparent independent growth of the maxilla and the mandible, felt that their development as a whole unit is dominated, not by growth, but by the neuromusculature associated with them and by the effects of the developing dentition. Thus he felt that, while growth itself may be beyond our control, we can modify or control these neuromuscular functions. Later in his conclusions he states that "the transitional dentition period is the most suitable time for dealing with and retraining neuromuscular problems enabling new patterns to be established as new teeth come into occlusion".

Ricketts (1979) writing on treatment in the mixed dentition says "our goals should include the making of skeletal changes, to utilize growth and to intercept habits and functional patterns, so as to establish harmonious relationships and the patient is given every chance of developing an occlusion as near to perfect as possible". Moyers (1973, page 459) writing
on timing of treatment, included in his reasons for treatment: to remove obstacles to normal growth of the face and dentition. To obtain and restore normal functions. Moyers included in treatment of the mixed dentition, the correction of posterior crossbites, to enhance guidance of growth and to intercept a developing malocclusion.

1.3.4 Reducing Treatment Complexity and Duration

Barnes (1956) referring to retention of the crossbite corrections, felt that the prognosis for their stability was significantly improved by their early correction. He later suggests that if the growth of the permanent alveolar bone can be compelled to occur about the teeth in their corrected positions, it becomes obvious that retention will be permanent.

Breitner (1940) when considering the arguments against early treatment felt that starting too early may create inordinately long periods of treatment, overworked teeth and surrounding tissues, sometimes the onset of caries, and often lead to mechanical abrasion. It could also cause abnormal physiologic problems and obscure psychological disturbances. Breitner concluded, however, that it is probable that the reverse may also be true in nearly all these examples, or that the above problems could be just as applicable to untreated cases.

Interceptive treatment should be of short duration and, if our goals of prevention are met, should reduce the treatment time in the permanent dentition. Tooth and supporting tissue damage due to premature contacts, caries onset due to overcrowding, difficulty of satisfactory oral hygiene, mechanical abrasion due to premature contact, physiologic disturbances of redirecting growth and muscle function in a more normal direction, and psychological problems created perhaps by asymmetrical or CIII
malocclusions are all positive rather than negative aspects of early treatment of posterior crossbites.

Korkhaus (1960) points out the more extensive nature of some conditions. Marked alteration of the jaw due to inhibition of growth or deformation is not a localised problem but a characteristic of a complex anomaly which extends beyond the immediate regions of the jaws. The proximity of the palate to the sinus regions of the nose make it clear that deformation of the maxilla coupled with a high palate must be accompanied by narrowness of the nasal cavity. Korkhaus suggested that Ear, Nose and Throat specialists often refer patients with mouth breathing problems for orthodontic treatment when they realise that malocclusion, and above all, narrowness of the jaws are the chief causes of impeded nasal function. Free nasal function can only be achieved by extensive widening of the palate. Later in his conclusions he adds that "if treatment is carried out early enough to release the inlocked occlusion, the other associated anomalies may be corrected spontaneously."

1.3.5 Traumatised Deciduous Teeth and their Supporting Structure

This indicator for early treatment is included by many authors. Cheyney (1959) included in his indicators for early treatment: "the presence of crossbites may be indicated by malpositioned individual teeth, sensitive or traumatised teeth, loose or retained deciduous teeth, or faulty occlusal restorations." His primary treatment objectives are, the removal of these interferences, the establishment of normal mandibular closure patterns, and redirection of the developing permanent teeth.

Wood (1962), Graber (1972) and others mention the problem of the traumatic interference of the deciduous cuspids as an aetiologic factor of
posterior crossbites.

1.3.6 General Considerations in Treatment Timing

Breitner (1940) quotes Angle (1907) saying "the proper time to begin treatment is as near to the beginning of variation from normal in the process of development of the dental apparatus as possible. Unless some physical condition of the patient exists, it is unquestionably a serious mistake, without the least argument in its favour, to defer the operation until all the teeth shall have erupted". Mathews (1966) felt that the patient should be treated as soon as possible commensurate with the maturation of the young child. By this he introduces the psychological maturity as well as the physical factors. It is the problem of management, I believe, which usually contraindicates treatment in the very young child. Most private practitioners, both in the literature and those with whom I have had direct communication, prefer to wait until the first permanent molars have erupted. When considering rapid expansion Haas (1970) suggests that the presence of the first permanent molar was essential to provide the additional anchorage necessary to achieve splitting of the midpalatal suture. An additional consideration may be the eruption or impending eruption of the upper lateral incisors, as their possible spontaneous alignment may aid in retention.

Moyers (1973, page 460) includes a valid consideration for contraindication of treatment as where there is no assurance that the result will be sustained, or if a better result can be achieved, with less effort, at another time.

Another major consideration in private practice would be the age at which the patient presents to the specialist's surgery. Quite often
patients are not referred for treatment until they have a full complement of permanent teeth.
CHAPTER 2
NORMAL MORPHOLOGY HISTOLOGY AND GROWTH

Linge (1972) suggests that interpretation of treatment results and tissue changes incident to mechanical expansion requires an understanding of normal growth and considerations of the morphology in the area under consideration. Melsen (1972) felt that an understanding of changes during expansion possibly vary at different ages due to the variations in normal morphology of these structures. Histological appearances of the inter-maxillary suture vary greatly according to different species of animals and at differing ages in Man. This may affect the choice of the appropriate technique for expansion. Ten Cate et al. (1977) also felt an understanding of sutural structures was necessary to evaluate the literature on this subject.

2.1 Anatomy (Timms, 1981)

Very generally the maxilla articulates with a number of bones that limit it posteriorly and superiorly. These are:

Cranial bones: the frontal and ethmoid bones.

Facial bones: Nasal, lacrimal, vomer, zygomatic, palatine and opposing maxilla (Figs. 2.1 and 2.2).

The paired maxillae unite with the palatine bones to form the hard palate or floor of the nose and greater part of the lateral walls of the nasal cavity. Posteriorly the palatine bones articulate with the pterygoid process of the sphenoid bone. The other significant articulation is that between the frontal and zygomatic bone at the lateral aspect of the orbit and the frontomaxillary suture at their union with the nasal bones.
The Right Maxilla

Fig. 2.1 Lateral view of the right maxilla (Liebgott, 1981)
The Right Maxilla

Fig. 2.2  Medial view of the right maxilla

(Liebgott, 1982)
2.2 The Sutures

Storey (1973) describes the nature of sutures as structures joining two bones by a connective tissue complex which have peripheral fibres inserted into the calcified bone margins. They permit translation of bones and marginal addition of bone tissue during growth and development, as well as movement of bones relative to one another during muscular function. They have a highly convoluted and interdigitating system in Man with an arrangement of fibres similar to that of the periodontal membrane.

2.2.1 The Midpalatal Suture

Persson (1973) used necropsy specimens from twelve 0 to 18 year olds who had died sudden deaths. His interest was on the structural arrangement of fibres and their growth patterns. Growth, according to Bjork (1966), ceased by 17 years of age. Persson divides growth into two stages; an early growing stage, up to two years of age, of vigorous growth, and a subsequent late growing stage, from 7 to 17 years of age, where growth slowed to an eventual adult stage when growth ceased.

The Anatomy: In the early growing stage the bones of the intermaxillary suture meet with chiefly flat parallel surfaces, more so in the posterior area than the anterior. Only in the nasal part did the suture show incipient serration. This developed with age towards the typical serrated suture. Bony obliteration of the oral serrated part of the transverse palatine suture was observed in one older specimen. In one other specimen of the oldest group, a narrow bony bridge united the maxillary bones. Melsen (1975) describing the morphology of the midpalatal suture divided its postnatal development into three stages.
The Infantile Period: The suture is broad and "Y" shaped with the vomerine bone placed in a "Y" shaped groove between the two halves of the maxilla (Fig. 2.3 a. and b.).

The Juvenile Stage: The suture becomes more wavy (Fig. 2.3 c. and d.).

The Adolescent Period: The suture is characterized by a very tortuous course (Fig. 2.3 e. and f.). A distinctive stratification of the connective tissue into three layers can be seen. In the lower part of the suture, the fibres from the periosteum were found to extend into the central layer of the suture parallel with two bone surfaces.

Histology: Two main patterns of fibre arrangement were evident within the suture according to Persson (1973). In the anterior part of the suture the tissue runs largely parallel to the bony margins; it seems to form a direct continuation of the periosteal tissue into the suture. However, with age and increasing tortuosity of the suture, transversely arranged fibres extend down from the nasal aspect. This results in a serrated transverse fibred nasal-half and a flat longitudinally orientated oral-half. The bones were lined by cuboidal osteoblasts and a readily recognised osteoid border strengthened the histological picture of rapid matrix production. With the development of a serrated suture, osteoblasts in resorptive lacunae frequently covered the trabecular surface. Staining showed the fibre content to be collagenous with only scattered isolated fibres positive for elastin. The fibre bundles showed a three-layered arrangement, with coarser bundles in the middle third of the suture. Fibre bundles were never found to pass uninterrupted across the suture during the growth stages.
Fig. 2.3 Development of the midpalatal suture

a) Diagrammatic representation of the midpalatal suture during the infantile stage of development.

b) Frontal section through the midpalatal suture of a 1 yr old boy.

(Melsen, 1975)

c) Diagrammatic illustration of the midpalatal suture during the juvenile stage of development.

d) Frontal section through the midpalatal suture of a 10 yr old boy.

(Melsen, 1975)
e) Diagrammatic illustration of the midpalatal suture during the adolescent stage of development.
f) Frontal section through the suture of a 12½ yr old girl.

(Melsen, 1975)

Persson felt that the observed variations in fibre orientation reflected functional variations or mechanical demands rather than real differences. The presence of fibre bundles passing continuously from one bone to another indicated that growth had ceased or was ceasing. Kokich (1976) refers to Pritchard and associates describing sutures as consisting of five intervening layers of cells and fibres between the adjoining bones. Koski (1968) believes these differences are only reflections of differing interpretations of growth mechanisms.

2.2.2 The Transverse Palatine Suture

The morphology of the transverse suture changed during palatal growth. Melsen (1975) describes it at birth as being broad and slightly sinuous. At
ten years it developed into a typical squamous suture in which the palatine part overlapped the maxillary part. Incipient interdigitation was also seen at ten years of age. After 13 to 14 years of age the suture becomes shorter and slightly wavy and the connective tissue between the two parts of the palate is narrowed. The lowering of the palate by nasal resorption and oral deposition accounts for the overlapping section of the palatine bone to disappear as the suture becomes shorter and slightly sinuous.

2.3 Growth in Sutural Areas

Osteoclasts and Howship's lacunae showed remodelling to be a predominant feature of growth in the palatine sutures. This pattern corresponds to observations of periosteal growth of the bones. Appositional growth takes place towards the oral cavity simultaneously with osteoclastic resorption on the nasal aspect. Thus the suture moved orally with the drift of the hard palate. This suggests that the selective occurrence of deposition and resorption demonstrated in sutural areas apparently takes place in the same system of remodelling acting on periosteal surfaces by which the overall shape of the bones is maintained. Thus Persson concludes there is no reason to make a distinction between sutural and periosteal growth.

Generally these observations did not lend support to the theories of an autonomous regulation of sutural growth, but favoured the hypothesis of a common mechanism regulating growth in the sutural area. One may imagine, however, that internal factors, fibre arrangement and properties of ground substances may play an essential role in a mechanical system regulating growth. That growth continued up to the age of 13 to 17 years of age is considerably longer than that assumed from histological studies by
Scott (1956) and Latham (1971), but it is in close agreement with observations by Bjork (1966). However, the data obtained by Bjork showed that great variation must be expected between individuals.

2.4 Closure of Sutures

Kokich (1976) studied age changes in the fronto-zygomatic suture from 20 to 95 years of age, to determine at what age sutural fusion occurs and at what age it is no longer possible to effect sutural remodelling. He found the available literature conflicting and inconclusive, and believed that the discrepancies in results showed that there were inadequate methods of documentation of earlier studies. Kokich looked at the fronto-zygomatic suture of human cadavers both histologically and radiographically to determine age changes. He found that this suture does not undergo synostosis until very late in adult life. Further that sutural fusion is a progressive process which commences as small areas of bony union occurring initially within the internal portion of the suture. It progresses to the orbital periosteal surface, but union is not found near the facial periosteal surface. Kokich concluded that the suture undergoes synostosis in the eighth decade of life, but may not completely fuse even then.

2.4.1 The Midpalatal Suture

Persson (1976) and Persson and Thilander (1977) investigated the midpalatal suture closure using necropsy specimens of the palate, taken at post-mortems, on twenty-four specimens 1.5 to 35 years of age. The tendency of the suture to be obliterated was described by the number of sections showing closure. The advance of closure with age was quantified by using an obliteration index. This was calculated as the relationship between the length of the obliterated section of the suture, and the total
oro-nasal suture length.

The earliest obliteration was found in a 15 year old girl, the oldest person without any union of the suture was a 27 year old female. Thus obliteration was demonstrated in the juvenile period, but with considerable individual variation. A more intense activity of closure was found during the third decade and it could be considered that the earlier bridges are few and apparently small in extent and that they would not significantly resist the forces of rapid expansion. The obliteration started earlier in the posterior part of the intermaxillary suture than its anterior part. The index values of sutural closure, showed a low degree of closure between 15 to 19 years and then showed a sudden increase between 20 and 24 years of age. There was also a significantly greater degree of closure found in the lower halves of the suture compared to the upper or nasal halves.

The results showed that closure of palatal sutures often begins at earlier ages, but there are large discrepancies in closure between different sutures and also between different parts of the same suture. There does seem to be some relationship between the age at which sutural growth ceases and the age at which it starts to close. Bjork (1966) found that growth at facial sutures was intimately associated with growth in height. It is also logical to presume that skeletal age also influences the start of closure, thus partly explaining the individual variation observed. Persson adds that some factor other than age apparently influences the further development of the obliteration process.

2.4.2 The Nature of Suture Closure

Two main patterns of closure were found. One pattern was made up of long bony spicules bridging the suture in areas of transsutural organized
tissue. Osteocytes were included in the matrix, though a distinct osteoblasts layer was not evident. Narrow bony bridges were frequently found to be resorbed by osteoclasts.

The other pattern involved irregular masses which were formed either, as free calcified bodies in the tissue, or connected to the margins by bony trabeculae. These demonstrated several transformation stages. They were interpreted as being bony spicules which had earlier bridged the suture which had been fractured or damaged during the earlier stages of closure.

The intimate relationship between the early stages of closure and the transsutural fibre bundles was demonstrated by histological staining methods. Areas of closely organized collagen fibre bundles appear to be a pre-requisite for the start of bony obliteration. Persson and Thilander also believed that bony spicules crossing the suture were fractured physiologically and sutures were re-opened by osteoclastic resorption and that these reactions during the early stages of sutural closure were the results of functional forces acting on the sutural articulations.

2.4.3 Clinical Implications of Sutural Closure

Persson and Thilander (1979) concluded that the closer the patient's age to physiologic suture closure, the less reliability can be expected in predictable results of heavy forces on sutural articulations. According to their study, remodelling of suture surfaces should be effective up to 20 years of age. In palatal splitting with rapid maxillary expansion devices it has been shown by Isaacson and Ingram (1964) and Wertz (1970) that most of the resistance to separation is due to circummaxillary structures. It again seems logical that the heavy forces involved would fracture minor synostosed areas in the palate. If a 5% synostosed closure is set as a limit
for splitting the intermaxillary suture, this will not be reached in most patients younger than 25 years of age.

Timms (1981) expresses the view that the clinical metering of treatment and rate of expansion by the presence or absence of pain is the only indicator for excessive force build-up. Two main factors are generally responsible. They are the rigidity of the facial skeleton and the mechanical interlocking and synostosis of the midpalatal suture. As a consequence pain is rare in juveniles. However, as the facial skeleton becomes progressively stiffer, the tensions are relieved more slowly. Timms stresses that expansion should not be continued in the presence of pain where there is no evidence of a superior medial diastema or of the suture opening. This then indicates the need for surgical assistance to assist in splitting the suture.

2.5 Maxillary Growth

Besides Linge's (1972) suggested need for understanding normal growth in order to understand the effects of maxillary expansion procedures, there is also the belief that the effects of resumption of normal growth following maxillary expansion procedures, and the possibility of "catch up" growth, contributes significantly to the discussion and comparisons of slow and rapid expansion at differing age levels. This is discussed further in Chapter 5.

2.5.1 The Maxillary Growth Pattern

(Bjork, 1966; Melsen, 1973; and Bjork and Skieller, 1977)

Growth in length: is sutural toward the palatine bone accompanied by periosteal apposition at the tuberosity region. In no case has growth in length by periosteal apposition been found on the anterior aspect of the
maxilla, apart from the alveolar process. Melsen (1975) found that at the age of 15 years, the transverse suture, in most cases, consisted of a narrow sheet of connective tissue with mature osteoblasts. On the posterior margin of the hard palate, appositional growth continued up to 18 years of age. These findings further suggest that a displacement of the sagittally orientated sutures, between the horizontal plate of the palatine bone and the posterior part of the maxillary ridge, most likely occurs simultaneously with growth in the transverse suture. Bjork and Skieller (1977) also note the remodelling changes on the anterior aspect of the maxilla associated with lowering of the palate and anterior nasal spine.

Growth in height: takes place at the sutural articulations of the frontal and zygomatic processes according to Bjork (1966). Bjork and Skieller (1977) also mention appositional growth on the lower aspect of the alveolar process associated with the eruption of the teeth. The nasal floor is lowered through resorption, together with periosteal apposition on the hard palate. Also note the lowering of the anterior nasal spine through resorptive remodelling. Melsen (1975) found that the nasal surface of the hard palate was characterised by resorption up to 14 to 15 years of age, after which it consisted of resting lamellar bone. The osteoclast activity was most pronounced in the area posterior to the transverse suture. The oral surface was characterised by apposition up to 13 to 14 years of age. In addition he found that remodelling of the posterior border continued up to 16 to 18 years of age and tended to cease earlier in girls than in boys. Melsen felt that lowering of the palatine bone most likely occurs as a displacement between the palatine bone and the pterygoid process of the sphenoid bone. If this displacement of the palate is less than the sutural growth which occurs lowering the maxillary complex, then the balance can be restored by an increased remodelling of the nasal floor. If this is the
case, the transverse suture would serve as a transitional zone between the two parts of the palate exhibiting different patterns of growth.

2.5.2 Direction of Facial Growth Attributable to Suture Orientation

Vertical changes were assessed by Bjork by superimposing cephalometric radiographs on their cranial fossa, and lines drawn through nasion and sella points. Another line was drawn through the anterior and posterior implants. The angle between these lines was taken as an indication of the direction of sutural growth. While average figures were given, the most significant result of this study was the large variation in direction, from almost purely sagittal, to purely vertical. It must also be stressed that the direction was apparently not linear, and if assessed annually would reveal a curved path. The most frequent pattern was mainly sagittal in direction during the juvenile period, and became more vertical during adolescence. Bjork and Skieller (1977) supported these findings of usually a forward rotation of the palatal plane, and that despite this, the nasal floor inclination to the cranial base is maintained as a result of compensatory differential resorption, greater anteriorly than posteriorly.

Transverse mutual rotation of the two maxillae is the description used by Bjork and Skieller for transverse growth direction. Comparing the increase in width between the anterior and posterior implants, the distance between the posterior implants increased, on average, three times as much as that between the anterior implants. That the lateral implants separate more than the anterior ones during growth indicates that the two maxillae rotate in relation to each other in the transverse plane. Due to this rotation, the length of the maxilla, when measured in the sagittal plane, becomes reduced. This rotation of the maxilla also results in the lateral
segments of the dental arch separating more posteriorly than they do anteriorly. Thus the distance between the molars increases more than the distance between the canines. At the same time the length of the dental arch becomes reduced in the midsagittal plane. This shortening of the dental arch has been ascribed to increased crowding of the teeth during development. Bjork and Skieller show, however, that it is also related to the transverse growth of the maxilla. A point to note is that this rotation is the reverse of that described by a number of authors for rapid expansion where the increases are greater anteriorly than posteriorly.

The Zygomatic Process: Characteristic in the development in length of the face is the change in position of the dental arch in the sagittal direction which occurs in relation to the infrazygomatic crest during growth. In a child the distal surface of the second deciduous molar lies behind the crest, while the mesial surface of the first permanent molar of an adult lies in front of the crest. According to the classical view, this change takes place as a result of remodelling of the zygomatic process. Resorption of the anterior surface and deposition at the posterior surface results in the process as a whole moving backwards on the body of the maxilla. Enlow (1966) describes this as progressive resorption from the anterior surface of the zygoma and the forward edge of the lateral orbital rim, bringing about a posterior relocation of these areas and thereby serving to maintain their relative positions with respect to the posteriorly growing maxillary body. Implants, however, on the anterior lower margin of the infrazygomatic crest retain their position in relation to the anterior surface of the zygomatic process. A differential apposition at the maxillary tuberosity compensated, more or less, completely for the vertical rotation of the maxilla. With the shortening of the maxillary length as a result of the transverse rotation in relation to each other there is no need for
remodelling of the anterior surface of the zygoma in an antero-posterior direction to take place.

The Alveolar process and dental arch: As described above, Bjork and Skieller found the dental arch has been displaced in an anterior direction in relation to the implants and the maxillary corpus. It can also be shown cephalometrically that the dental arch as a whole is displaced forward in relation to the anterior implants. The forces underlying this shift cannot be regarded as fully clarified. However, the forward drift of the dental arch results in a decrease in the available space for the incisors, and may be an etiological factor in late secondary crowding. The arresting of this process during maxillary expansion may contribute to space regaining during expansion procedures.

2.5.3 Sutural Growth Rate

Bjork (1966) found that during the infantile period the growth rate falls steeply, it then changes to a slower rate of retardation during the juvenile period. This continues until a well defined prepubertal minimum. During adolescence, the rate increases to a pubertal maximum, and then decreases toward adulthood when growth ceases (Fig. 2.4). These growth stages are associated with hormonal development and genetic controls. The timing of periodic variations are inter-related, an early prepubertal minimum being followed by an early pubertal maximum and early adulthood. Puberty and completion of growth occur about 1½ to 2 years earlier in girls than in boys. In addition Bjork found that sutural growth ceased at an average of 17 years of age, which was 2 years before body height ceased increasing and condylar growth was slightly later still. Individual variations in these timings are great, especially for condylar growth which has been recorded up to 23 years of age.
Fig. 2.4  Periods in the development of the child divided according to the rate of growth.

(Bjork, 1966)

2.6 Radiographic Study Using Maxillary Implants

Isaacson et al. (1976) included in their conclusions that:

1) Tooth movement relative to the alveolar bone can be described precisely only by superimposing on fixed points in the bone. Implants are the best known way today of achieving this. Remodelling occurs extensively on bony surfaces making them too unstable for use as landmarks.
2) Growth can be disproportionate in either the vertical and/or the antero-posterior planes of space. If the vertical increments of the anterior face differ from those of the posterior face, rotations will occur. This growth is accompanied by dental compensations that tend to mask these rotations.

Bjork (1966) felt that by using implants as fixed reference points it is possible to make an objective comparison between the importance of sutural growth with that of periosteal remodelling brought about by apposition and resorption. Bjork, through experience gained over a number of years, found there are four sites in the maxilla where implants may be placed without risk of changing their position.

At the early juvenile ages, they can be inserted in the hard palate behind the deciduous canines. The stability of these implants is dependent on the extent to which the nasal floor is lowered by the resorptive process. Where this is marked, it is not certain that they will remain undisturbed until adulthood. After eruption of the permanent incisors, an implant is inserted below the anterior nasal spine on each side of the nasal suture on a level with the root apicies. These implants almost always remain unchanged up to adult life, except in a few instances where the resorptive lowering of the anterior nasal spine is particularly great, where it may be necessary to replace them. Being near the median plane these implants are useful for analysing sutural growth in the sagittal plane, and examining growth in width of the maxilla in the anterior part of the suture.

Implants are placed in the zygomatic process of the maxilla on both sides of the head, lateral to the alveolar process to avoid being disturbed by the eruption of teeth. Two implants are placed to act as checks that one is
not disturbed. These implants are suitable for measurement of growth in width of the maxilla in the central part of the median suture. Implants have also been placed, with good results, at the border of the hard palate and alveolar process, medially to the first permanent molar, Krebs (1964). Bjork and Skieller (1977) while studying the change in position of the zygomatic process relative to the maxillary base, described in section 2.5.2, came to the conclusion that, the anterior contour of the zygomatic process was extremely stable, and that it is possible to regard this anterior contour as a stable reference structure in the growth analysis of the maxilla.
CHAPTER 3
SLOW EXPANSION TECHNIQUE

3.1 Appliances Used for Slow Maxillary Expansion

Korkhaus (1960) suggested that there is a variety of appliances for expansion including fixed, removable, active, passive, rapid and slow expansion techniques.

3.1.1 Passive Appliances

Passive appliances include the functional orthopedic appliances, for example, the Activator. With these types of appliances the overall expansion, despite lengthy treatment, remains insufficient for use in marked cases of compression of the jaws or for correction of posterior lingual crossbites. McDougall et al. (1982) considered in some depth the expansion effects of Frankel therapy and concluded that there is expansion of both maxillary and mandibular arches.

3.1.2 Active Expansion Appliances

Removable plates (commonly used in Europe). They have direct contact with the surface of the palate and lingual slope of the alveolar process. As a result of their action being extended to both dental and soft tissue surfaces, tipping movements of the buccal teeth in a transverse direction are only slight and there is a definite expansion of the apical base, as demonstrated by Skieller (1964) and discussed later in this chapter. She shows that there is not only development of the buccal segments of the alveolar process, but a definite expansion of the vault of the palate with subsequent development of the floor of the nose and improvement in nasal airway.
Wickwire (1973) describes a simple technique for correction of bilateral maxillary constriction in the primary and mixed dentitions. Skieller's appliance is a removable split acrylic plate, adequately clasped for retention, usually with Adams clasps on the first deciduous molars and first permanent molars. It has an expansion screw centered on the midpalatal raphe (Fig. 3.1).

The patient activates the appliance by turning the central screw one quarter turn every two days. The patient may have problems reseating the appliance and it may be advisable to activate it in the mouth. As the patient adjusts to the appliance, activation may be increased to every day and if problems arise slow down again.

The appliance itself is used as a retainer for at least three months. Wickwire suggests it may be necessary to add occlusal guides in the form of acrylic guide paths to control mandibular deviation problems.

The problems with this form of appliance include breakage, distortion or loss, and the requirement of good patient co-operation. The patient is left, not only with the choice of wearing it or not, but also the problems encountered during activation with retention of the appliance in the mouth. Also in the unfortunate event of leaving the appliance out late in treatment, rapid relapse occurs and results in having to go back to the beginning. The major problem encountered is one of retention, as the appliance is expanded, the molars tip and clasps leave the undercut areas. Wickwire has suggested the addition of acid-etched material to the buccal surface of the retaining teeth to increase the depth of undercut areas.

It is the writer's belief that the majority of these problems are associated with any removable appliance and thus, given the choice, I would
Fig. 3.1

a) Removable expansion plate used by Skieller (1964)

b) The appliance in situ
   (Skieller, 1964)
always elect to use a fixed appliance if possible.

**Fixed active appliances.**

Korkhaus (1960) felt that there was little difference between the fixed and removable appliance. The buccal movement of the teeth carried out with a fixed lingual arch is accompanied by obvious expansion of the palate. He also felt that apart from the tipping movement of the teeth, there was also bodily movement of the teeth and alveolar process, which may be associated with the stimulus of mastication. This is considered further in Chapter 5.

Korkhaus (1960) and Lebret (1965) both favoured the acrylic plate type of appliance with the central expansion screw. Lebret felt that the labiobuccal appliance effects were largely confined to the alveolar process, while the expansion plate had pronounced effects on the whole palatal contour. The extent of the change and his suggested post-retention stability of the increased width at the top of the palatal vault point to involvement of the midpalatal suture. In his conclusions, he suggests that, the increased palatal width is partly explained by cellular proliferation at the midpalatal suture. Korkhaus explained the differences in terms of the acrylic acting directly on the alveolar process. He feels that this gives more extensive and far reaching subsequent development in breadth. In the mixed and permanent dentitions the surface action on the palate, while reshaping the alveolar process, moves the teeth and succedent tooth germs to a new position. Thus the erupting teeth are not tipped and there is less tendency for relapse.
3.2 The "W" or Porter Appliance

This was described by Buck (1970) for correction of posterior crossbites, as a modified Porter lingual arch (Fig. 3.2). This appliance he described as having bilateral extension arms to include the deciduous teeth. He used preformed bands on the first permanent molars with a lingual arch of 0.036" stainless steel wire contoured to within one millimetre of the palatal surfaces. The appliance was expanded six to twelve millimetres on insertion, and adjusted monthly. He felt it should be removed for adjustments, although some operators elect to adjust it in the mouth on alternate visits. It can also be constructed with vertical posts soldered to the wire to fit into sheaths on the lingual aspects of the bands, thus only the wire need be removed for adjustments.

Buck suggests removing the extensions onto the deciduous teeth and grinding out any occlusal interferences. I presume his intention is to more easily achieve correction of the permanent teeth, although I feel it leaves out the concept of correction of the deciduous tooth position producing a more favourable positioning of the underlying tooth germ. The concept of reducing the extension arms unilaterally may be applicable to true unilateral crossbites, thereby increasing the anchorage potential on one side relative to the other. Later in his discussion section Buck suggests that treatment should be completed in six to twelve weeks, if unsuccessful after 16 weeks, the appliance should be removed and a re-assessment made. The posterior cuspal interdigitation makes this tooth movement self retaining and no special retaining device is required.

Harberson and Myers (1978) considered that while the increased width gained from the "W" arch could result from the buccal tipping of the teeth,
Fig. 3.2. a) The "W" Appliance  
b) Porter Appliance.  
(Harberson and Myers, 1978)

some effect from opening of the midpalatal suture was also involved.

They did a study of eleven children, in the deciduous or mixed dentition stage, with posterior functional crossbites. The arch was made from 0.036" stainless steel wire and activated by opening the three angles until it was activated over a distance of half the width of a molar tooth on each side. Treatment time was three to eight weeks and retention extended one to three months as the cases indicated. Radiographs were taken pre-operatively, at two-weekly intervals during treatment, and post-operatively at least one month after completion of expansion. The appearance of a radiolucent
line in the midpalatal suture area was considered to be evidence of midpalatal suture opening.

The results indicated that eight of the ten successful results showed evidence of midpalatal suture opening during treatment. Post-retention radiographs showed evidence of obliteration of this opening. This, they concluded, indicated that the correction achieved for these patients was accomplished, at least in part, by an increase in maxillary width due to opening of the midpalatal suture. In the remaining cases correction was due entirely to buccal tipping of the posterior teeth.

3.3 The Quad-Helix Appliance

As suggested in the introduction, a more detailed consideration is given to the quad-helix appliance as a method of slow expansion for comparisons with rapid expansion technique.

3.3.1 The Appliance

Birnie and McNamara (1980) include a good description of the design features of the quad-helix appliance (Fig. 3.3). These features include:

The anterior bridge should be straight and lie along a line joining the distal surfaces of the upper canines. I prefer this positioning to that of Bench et al. (1978) who suggest it should be placed as far forward as possible with the horizontal arm over the papillae. This would seem to be too far forward, it would make intra-oral adjustments extremely difficult. There may also be interference with the lower anterior teeth and possible irritation to the tip of the tongue.
Fig. 3.3

a) The quad-helix appliance. (Birnie and McNamara, 1980)

b) The force activation characteristics of the appliance produces, not only an expansion of the maxillary buccal segments, but also a megibuccal rotation of the banded teeth.

(Chaconas and de Alba, 1977)
The anterior helices should be wound so that they lie on the palatal surface of the appliance, thus holding the spring away from the mucosa. The appliance should be close to, but not in contact with, the palatal mucosa so that there is minimal interference with tongue movements.

The posterior helices should be sloped so that they lie parallel to the palatal vault, and lie sufficiently distal to the molar bands to avoid flowing solder into them. With stainless steel wire care must be taken to avoid annealing the wire at the solder point. If "Elgiloy" preformed wires are used, as supplied by the Rocky Mountain Company, in the form of blue Elgiloy, heat treatment will be necessary to re-establish the spring in the wire before insertion in the mouth.

The lateral arms should extend forward far enough to control all the teeth to be moved buccally; that is, usually to the deciduous canines.

3.3.2 Indications for Slow Expansion

Birnie and McNamara (1980) suggest that slow expansion is indicated for the buccolingual expansion of the upper arch where the degree of expansion required can be obtained by tilting the teeth in the buccal segments. The appliance may therefore be used to correct unilateral and bilateral crossbites or expand mildly crowded arches before final tooth alignment. Sandham (1979) extends this to include:

- Unilateral crossbites in the mixed dentition.
- Where there is a functional deviation on closing with mild bilateral crossbites in the mixed dentition.
- Where lingual angulation of the upper molars is contributing to the crossbite.
Bilateral crossbites of skeletal origin, and crossbites in the permanent dentition have variable responses to any desired orthopedic effect. The appliance should be regarded as interceptive and usually requires further fixed or removable appliance therapy.

Further indications for slow expansion suggested by Birnie and McNamara are contraction of maxillary intermolar width and rotation of maxillary first permanent molar teeth. It should be noted that in correcting the position of the mesiopalatally rotated molar, the distobuccal cusp of the tooth moves distally as well as buccally, thus helping to correct any tendency toward a CIII molar relationship (Fig. 3.3b).

Ricketts (1979) suggests that in addition to the above; CIII conditions in which the arch needs to be protracted using CIII traction could be treated with slow expansion. The writer feels that this is possibly encroaching on the suggestion that in rapid expansion, disarticulation of the facial sutures makes the maxilla more amenable to CIII traction. Ricketts also modified the appliance, discussed below, to make it useful for correcting habits such as tongue thrusting and thumb sucking. He also includes either unilateral or bilateral cleft palate conditions for which he previously used the "W" appliance.

3.3.3 Modifications to the Quad-helix Appliance

Increasing the number of helices; Birnie and McNamara (1980) suggest extra helices may be added to the anterior extensions of the lateral arms to procline upper laterals. Sandham (1979) also describes the addition of light wire springs to the inner arms to effect minor anterior tooth movements, including the retraction of canines.
Decreasing the number of helices; The anterior helices may be replaced by a palatal acrylic button if space maintenance and derotation of the molars rather than expansion is required. A true bihelix is usually (by convention) referring to an appliance for the lower arch. Ricketts (1979) referring to the addition of a palatal acrylic button called it a modified Nance appliance or 2 in 1 appliance.

The addition of habit breaking auxiliaries; These are described by Bench et al. (1978), Birnie and McNamara (1980), and Ricketts et al. (1979). They include the addition of bars anteriorly on the inner arms to discourage thumb sucking habits. The further addition of spikes on the horizontal arm is also described, for additional control of thumb sucking or tongue thrusting habits.

Sandham (1979) also describes in his modifications McKeag slots on the banded teeth, so that the wire section can be easily removed. A further modification suggested by Ricketts et al. (1979) was the addition of double buccal tubes on the bands to take headgear for extra oral traction. If Kloehn headgear is utilized the helix portions may be cut away, maintaining the outer arms only. The gained expansion is then maintained by slightly expanding the inner face bow.

3.3.4 Contraindications for the Use of the Quad-helix Appliance

Chaconas and Caputo (1975) felt that the quad-helix was contra-indicated where buccopalatal expansion of the upper arch is required but cannot primarily be obtained by tilting the teeth in the buccal quadrants.

The purpose of their study was to compare various orthopedic forces produced within the craniofacial complex with a number of different
appliances. They compared the Haas rapid maxillary expansion appliance, the Minne expander, the Hyrax screw, the quad-helix, and a removable maxillary expansion device. Their conclusion regarding the quad-helix was that it proved to be the least effective orthopedic device. "Although effects of palatal separation were seen with increased activation, the appliance primarily affected only the posterior teeth."

3.3.5 Construction and Activation of the Quad-helix Appliance

The same basic principles are utilized as for the "W" arch, described earlier, with the design characteristics described by Birnie and McNamara (1980) in section 3.3.1. Sandham (1979) used 0.9 mm (0.036") stainless steel wire. Chaconas and Caputo (1975) used 0.036-0.038" stainless steel wire also, while Ricketts et al. (1979) after their research designed his appliance blanks in 0.038" Elgiloy wire, their object being to develop 500 gms of force for orthopedic movement when desired.

Activation

The initial expansion activation is placed in the appliance prior to cementation. Chaconas and de Alba (1977) recommend an activation of 8 mm posteriorly at the molar bands. Birnie and McNamara (1980) repeat this figure and additionally suggest a 1.5 cm expansion anteriorly. The anterior helices are expanded first to gain the posterior activation, then activate the posterior loops to achieve the anterior activation. If marked molar rotations are present, the lateral arms should be adjusted so that they do not contact the other buccal teeth until the rotations have been corrected. Further discussion of activation and forces produced by slow expansion is included in chapter 5.

Ricketts (1979) reports that he allows 6 weeks between adjustments and
at the second visit, intra-oral adjustments are made by pinching the wire, with a three-prong plier, directly anterior to the posterior loops. The anterior adjustment, between the anterior loops, is independent of the molar activation but you need three bends to compensate for each other. The writer finds this description of intra-oral adjustments difficult to accept as the activations described will affect the posterior expansion favourably, but serve to contract the lateral extension arms unless these are also expanded, thus making five adjustments. While I accept that three adjustments on the "W" appliance, at the anterior and posterior angles or bands, will effectively activate it intra-orally, I feel you need to activate either, all four helices in some way, or all five of the wires between the helices and the lateral extensions of the quad-helix. Chaconas and Caputo (1982) were surprised to find, in their model experiments, that the intra-oral adjustment of the quad-helix actually decreased the expansion force and, as explained above, this would be dependent on their method of activation. I would accept that if the object is to derotate molars, this could be achieved by intra-oral adjustment. If, however, true activation of the quad-helix appliance is desired, both anteriorly and posteriorly, the appliance should be removed, activated, and recemented. In this manner, the amount of activation can be assessed to ensure sufficient magnitude of force is maintained to achieve the desired expansion, intra-oral adjustments remain of dubious value.

3.3.6 Management and Retention of the Appliance

Treatment time should be approximately three months, then leave the appliance in place as a retainer for a further two months. In order to allow for a small amount of rebound, which occurs when the appliance is removed, the case should be overtreated until the palatal cusps of the upper arch overlie the buccal cusps of the lower arch. The problem of retention should
not occur with correct diagnosis, as the buccal tipping of the teeth should only produce good intercuspidation with the lower arch as it settles and thus should be naturally retained; this is discussed further in section 3.3.8 when considering problems with this appliance.

3.3.7 Ricketts' Analysis of the Appliance

Ricketts (1979) describes the quad-helix as being developed from the original Coffin spring concept as the "W" palatal expansion appliance used to treat cleft palate conditions with collapsed maxillary arches. The appliance could be preferentially activated either anteriorly or posteriorly depending on the requirements of the case. Later Ricketts added the helices and it was assumed to be simply a dental expansion appliance. The modification of the helices was proposed to increase the range of force application, allow increased flexibility, increase molar rotational ability, and refine adjustment capability. It was later also believed to enhance the orthopedic effect in younger patients.

Ricketts (1975) states that he found 2 to 3 mm of space would open up mesial to the upper molars which could change a mild CIII to a CII molar relationship. After the advent of suture splitting, Ricketts on checking previous records realized that the nasal cavity had widened more than normal growth expectations. He thus introduced the concept that widening of the facial bones (orthopedic effect) at the origin of some of the facial muscles, will effect a change in the environment surrounding the dentition. Palatal widening affects the floor of the nose and enhances nasal breathing which may change tongue positioning. It could also alter the origins of the caninus muscle and thus alter the pressure effect on the upper and lower canines. Ricketts also compares the quad-helix effect to that of extra-oral traction and states that if extra-oral traction is used over a period of time
maxillary division will frequently occur if you avoid banding the front teeth and thus tying the two halves of the maxilla together. Indeed if you do not expand the molars as you move them distally you may unintentionally move them into a crossbite relationship.

With the advent of rapid expansion and the palatal splitting effect, it was observed by Storey (1973) that the retention period was a problem, because the new bone formed so rapidly it was an immature young type and thus unstable. With the slower quad-helix expansion, the orthopedic splitting effect is not as dramatic and separates in pace with the new bone formation and remodelling. Storey felt that perhaps this led to better stability, although this is still unproven. Ricketts (1975) and Ricketts et al. (1979) feel that after 6 months following expansion the results of rapid expansion and the quad-helix are essentially the same in the extent to which the nasal floor is involved.

3.3.8 Problems with the Quad-helix Appliance

- The outward (buccal) tipping of the teeth:

Ricketts et al. (1979) consider this the main problem with the appliance. They felt that this could be countered to some extent by tourquing the roots buccally with a rectangular arch wire following expansion. At first inspection, tipping would appear to be undesirable because of the tendency towards rapid relapse. The downward and outward positioning of the upper buccal teeth is followed by an attempt on Nature's part to upright the roots. The problem remains that this natural uprighting effect is unpredictable and certainly not always dependable and thus the option of buccal root torquing must be kept in mind. The rationale behind this natural uprighting is associated with the change in occlusal contacts
(Fig. 3.4). With the retention appliance contact on the palatal gingival margin of the upper molar acting as a fulcrum. The contact point of the lingual incline of the lower buccal cusp and the buccal incline of the upper lingual cusp supplies a force tending to rotate the upper molar buccally. Thus the effectiveness of the natural uprighting would be dependent on the effectiveness of the cuspal interdigititation and the original inclination of the curve of Monson. As will be discussed in Chapter 5, the effect is also related to the stress and strain factors within the skeletal structure and the patient's ability to reduce these abnormal stresses.

Fig. 3.4 Uprighting forces of the occlusion
- Failure to overexpand and retain sufficiently

The literature on this aspect, almost without exception, recommends overexpansion to allow for an initial relapse when the appliance is first removed. This is seen particularly where there is an absence of improved nasal function and the tongue remains too low in the oral cavity. Always overexpand until the palatal cusp of the upper molar overlies the buccal cusp of the lower. Retention and the need for an appliance is again dependent on the cuspal interdigitation and the original inclinations of the buccal teeth. If we are to get favourable natural uprighting of the buccal teeth in Fig. 3.4, the lingual retention appliance is necessary to provide the fulcrum for the buccal movement of the roots and to prevent the lingual movement of the crown. This could also be related to the suggestion that lateral expansion of the lower buccal segments can be achieved as a positive byproduct of similar expansion in the upper arch. It should be stressed, however, that while the changes in the upper arch occur over a short period of time, they must be maintained, and retained, for lengthy periods to allow for the response to occur in the lower arch.

- A third problem related to the quad-helix could occur due to poor adaptation of the helices to the palate. If they remain too far downward and backward in the mouth, the tongue will frequently be disturbed and creased during function. This problem is removed if care is taken to adapt the helices correctly at the time of original construction.

3.4 The Effects of Slow Expansion

3.4.1 The Midpalatal Suture

As has already been noted, Harberson and Myers (1978), using the "W" appliance, Ricketts (1975) and Ricketts et al. (1979) considered that slow expansion does have an orthopedic effect on the midpalatal suture and the
floor of the nasal cavity.

Implant studies have been done by Skieller (1964), Cotton (1978) and Hicks (1978) using differing methods of expansion and in Cotton's case monkeys rather than human patients.

Skieller (1964) using Bjork's implant method, used a sample of 20 children, 6 to 14 years of age, and an acrylic plate. It had an adjustable steel screw with square guide pins to reduce the amount of play and was stable up to 8 mm of expansion. It was adjusted one quarter turn per day producing half a millimeter of expansion per week. Bjork's (1955) metallic implants were inserted bilaterally in the zygomatic process of the maxilla and below the nasal spine on each side of the midpalatal suture. Cephalometric profile and postero-anterior radiographs were taken prior to treatment and at annual examinations. Additional radiographs were taken when the expansion was stopped, and at the end of the retention period. Measurements were taken from the models in two areas, between the distal surfaces of the lateral incisors, and between the first molars. Measurements from the postero-anterior radiographs were used to study the growth at the midpalatal suture and the increase in width of the maxillary base using the increases in the measurements between the implants in the zygomatic processes. The increase in width of the nasal cavity was measured between the antral walls one centimeter above the lowermost contour of the nasal cavity. This measurement was also used by Krebs (1959) in his study of rapid maxillary expansion.

The results obtained suggested that there were increases in all the above zones during treatment. During retention the width of the dental arch remained unchanged, while that of the maxillary base continued to
increase slightly. After retention, a reduction in the width of the dental arch was recorded, whereas the maxillary base and nasal cavity increased in width. These results are explained by relating the effects to normal growth and stimulation of growth during the period of expansion. Using rapid expansion, the changes are so rapid that growth during the expansion period can be disregarded. This should be further considered in view of Storey (1973) who says that once the suture is separated, growth stops until the integrity of the suture is re-established by formation of new bone. In slow expansion continued growth has to be taken into account.

The decrease in dental arch width is probably explained by the relapse of dental tipping effects, or related to, as Cotton (1978) suggests, the soft tissue and extended peri-oral musculature as etiologic factors in this response. This is further discussed in Chapter 5 in relation to alveolar stresses and strains.

Cotton (1978) used 4 Rhesus monkeys as his subjects, with Tantalum implants to facilitate interpretation of cephalometric radiographs, to serve as landmarks for documenting linear and angular changes. The appliance was a split acrylic plate secured to the buccal teeth with bands, and a modified Minne expander housing to contain a long stainless steel open coil spring. In addition threaded brass tubes were soldered to the buccal aspects of the upper molar bands with threaded wire segments engaged in these tubes at recording sessions to produce a serial record of molar angulation changes.

The compressed spring length produced a 1 lb force with 0.016" wire and 2 lb force with 0.018" wires. The springs were designed to deliver the prescribed force when compressed to a length of 10 mm and were adjusted
to the desired length at weekly intervals.

The purpose of this study was to examine the skeletal versus dental, linear and angulation changes incident to slow palatal expansion. His hypothesis was that palatal expansion without significant excess dental expansion can be accomplished by means of a constant low magnitude force system applied simultaneously to the palatal vault and buccal teeth. The skeletal response to such forces may allow maintenance of sutural integrity resulting in earlier physiologic stability and a shorter retention period clinically.

Records were taken during treatment and at monthly intervals during retention. Measurements were taken at the premolars and molars. Postero-antérior cephalometric radiographs were taken and calipers used to measure transverse linear changes between homologous facial implant pairs. Reference lines were drawn between the implants at various levels to produce angular measurements for amounts of tipping of the maxilla in relation to the cranial base and tipping of the first permanent molar in relation to their respective maxillae.

Cotton's results show that palatal expansion occurred in all three experimental animals. Total expansion varied from 6.9 mm to 9.6 mm, that attributable to sutural expansion varied between 3.5 mm to 4.4 mm. Tooth movement ranged from 36% in young animals to 55% in the older one. The maxillary expansion was measured between implants in the zygomatic process. It was most significant in the maxillary process, less so for the frontal and temporal processes. These latter increases could be interpreted as being due to normal growth. Cotton concludes that midpalatal separation did occur with continuous forces of 1-2 lbs and that the midpalatal implant
increases contributed 45 to 64% of the total increase depending on the age of the subject. He found that this increase was not substantially different from studies involving rapid maxillary expansion.

Hicks (1978) did a clinical study, the aims of which were, firstly to determine the reliability of Cotton's method under clinical conditions; secondly, to present preliminary clinical data showing the relative skeletal and dental responses to a 2 lb continuous load. He used five children aged 10 to 15 years. The appliance and metallic implants were similar to Cotton's. The records were obtained from dental casts and radiographs with allowances for differences in head positions having insignificant effects on his measurements.

It took 8 to 13 weeks to complete the expansion. The appliance was well tolerated by all subjects. Only one subject developed an anterior diastema, but radiographs showed visual evidence of midpalatal suture widening in several subjects. Retention was varied with one subject maintaining fixed retention, three used removable appliances as retainers, and one patient had no retention.

In his observations Hicks found that the expansion was slightly greater posteriorly than anteriorly, both dentally and skeletally. That is, the intermolar implant distance showed a greater net increase than the zygomatic implants. A ratio of net skeletal increment to net dental increment indicated that approximately 27% of the linear expansion was due to separation of the maxillary segments at the midpalatal suture. In his summary he shows the variation in his subjects. Separation of the maxillary segments accounted for 16% of the separation in a 15 year old, and up to 30% of the linear dental arch increases in younger patients. Facial tipping
of the molars and skeletal segments accounted for the remainder of the increases in dental arch width.

Frank and Engel (1982) did a cephalometric study on the effects of the quad-helix appliance. It was based on twenty patients; nine females, eleven males, with a mean age of 10 years 3 months, ranging from 7 years 2 months to the eldest boy of 17 years 6 months. Postero-anterior and lateral cephalometric radiographs were taken at three stages: prior to treatment ($T_1$), six months after treatment commenced ($T$ prog) and at completion of orthodontic treatment ($T_2$). Dental casts were also measured at $T_1$ and $T_2$ for transverse changes in maxillary and mandibular intermolar width.

On frontal cephalograms linear measurements were taken for:

- Nasal width (the maximum width of the nasal cavity)
- Maxillary width (between right and left jugal processes, located at the intersection of the outline of the tuberosity and zygomatic buttress)
- Average maxillo mandibular width (from jugal processes of the maxilla to the fronto-facial plane on the respective sides)
- Average molar relation (average distance between buccal surfaces of the upper molar to the lower along the occlusal plane)
- Mandibular intermolar width (projected from the buccal surfaces to the occlusal plane)
- Maxillary intermolar width (as for the mandible)
- Maxillary intercanine width (between incisal tips of the maxillary canines).

The dental casts were also measured for transverse changes in maxillary and mandibular widths using a Boley gauge to the nearest 0.1 mm. Tracings were corrected by computer to allow for normal cranio-facial
growth to obtain the net effect of the quad-helix. The mean, standard deviation, and student "t" tests were obtained for all three time intervals and a number of regression analyses done on the results obtained.

The results from $T_1$ to $T_{(prog)}$ showed a mean orthopedic gain of 0.92 mm increase with 5 out of the 20 subjects increasing 2.7 mm or more. I have omitted most of the remaining figures, particularly those comparing the beginning and end of treatment, because they give no details of what orthodontic therapy was utilized after removing the expansion device. They do mention that extra-oral traction was used on some patients which would have undoubtedly influenced the final maxillary expansion. At best it could be claimed that the follow up treatment acted as prolonged retention for the expansion achieved, but the final measurements must have questionable validity in relation to the original quad-helix treatment. The remaining problems of sample size, errors involved with radiographic tracing, and smoothing out of norms by computer analysis have not been discussed in the results, but I offer these as further grounds for questioning the results obtained. Despite these criticisms the positive conclusions reached are in agreement with the majority of authors previously quoted. These conclusions include:

"That moderate orthopedic expansion is definitely possible with the quad-helix, but only slight orthopedic change was consistently demonstrated." A ratio of 6:1 was obtained indicating that, for every millimeter of orthopedic or skeletal change there is 6 millimeters of orthodontic or dental change.

"Patients should be overtreated to allow for relapse." From this study dental expansion followed by orthodontic therapy showed little relapse. The
authors supported the concept that slow expansion takes place at a rate to which the facial skeleton can respond by physiological movement. It is stable and demonstrates less relapse. With their follow-up therapy confusing the effects of the expansion appliance, particularly with regard to stability, I am not sure how the authors reached this conclusion.

"The most stable cases were those that had normal nasal widths and narrow maxillary widths." This would seem to suggest a narrow maxilla on a normal cranial base; perhaps in reality it is really a dental width deficiency on a normal maxillary base and 'little orthopedic change was required.

"These cases requiring the greatest orthodontic change before treatment showed the greatest orthopedic results." Here it seems logical that those patients who had the appliance in place longest would achieve the greatest orthopedic effect.

3.4.2 Molar Angulation Changes

Cotton (1978) found that the overriding angular changes that were predictable were the immediate post-expansion decreases of molar angulation relative to the maxilla. The molar angulation changes during expansion were unpredictable and often asymmetrical. He also observed that skeletal tipping was minimal. The head films demonstrated that the greatest change in the transverse direction occurred in the lower levels of the maxillary bones, becoming less in the more superior regions of the cranio-facial complex. The slight decrease in the interimplant distance in the frontal processes of the maxilla suggests that lateral rotation and/or tipping of the maxillae does occur during slow expansion. This demonstrates a triangular separation of the maxillae in the frontal plane.
In his discussion on angular changes, Cotton refers to Haas (1961) describing lateral bending of the alveolar process; Krebs (1959, 1964) and Starnbach et al. (1966) are also referred to regarding palatal angulation changes. These authors are considered in more detail in the discussion of rapid expansion therapy in Chapter 4. Cotton concludes that skeletal and dental tipping were unpredictable during expansion. Skeletal tipping, however, was less than that reported with rapid expansion techniques. He also found that younger animals demonstrated a tendency for maxillary tipping to return to its original inclination.

Molar tipping, while it varied in each animal during expansion, consistently had a 10° decrease during the post-expansion period. He related this to the stretching effect of the attached palatal mucosa. This may explain why in this study regardless of whether their initial angulation increased during treatment or not, there was still this decrease following expansion. He further suggests the possible effects of the stretched perioral musculature, but this is difficult to assess in animal experiments as they have been expanded from a normal to an abnormally expanded condition.

Hicks (1978) confirmed clinically that the angular changes between left and right molars, and between maxillary segments within each subject were asymmetrical. In his conclusions he also suggests that facial or buccal tipping of the maxillary teeth occurs initially, but did not increase substantially relative to linear increases in the latter phases of expansion. This finding suggests that the linear increases in linear arch width, observed towards the end of treatment, were due to bodily translation of the teeth and maxillary segments, rather than an increasing rate of tipping of the posterior teeth. The clinical significance of the asymmetrical skeletal
separation of the maxilla has not been adequately investigated. Further studies requiring accurate and reproducible radiographic procedures are necessary in order to assess the frequency of various response patterns occurring within individuals. These studies will require large numbers of individual subjects in order to relate these patterns to clinical problems and the adverse effect of repeated radiographic examination may preclude future evaluation by radiographic means.

3.4.3 Nasal Changes

Ricketts et al. (1979) are quoted earlier as saying that "it appears after six months that the effects of the jack screw and quad-helix are similar in extent of final nasal floor involvement." This is difficult to support in the literature on slow expansion. Frank and Engel (1982) found an increase during their expansion of 0.8 mm with a standard deviation of 1.98 mm, and make no comment on the size of this deviation. This was statistically significant at the p = 0.10 level. Their later figures do not indicate significantly different effects from normal growth. Cotton (1978) and Hicks (1978) do not include nasal widths in their measurements. Skieller (1964) indicates that she does measure the dimensions of the nose but makes no reference to it in her discussion.

3.4.4 Lateral Cephalometric Changes

Hicks found the only significant changes in superimposed cephalometric radiographs were a slight lingual tipping of the maxillary incisor and a slight forward movement of the maxillary implants relative to the anterior cranial base. The mandibular plane remained unchanged. Frank and Engel (1982) did more detailed analysis of their records. The only significant changes they found during the expansion therapy were a slight bite opening which they explained by changes in the occlusion. Also the palate moved slightly
downward during the expansion phase as evidenced by an increase in maxillary height.

3.4.5 Mandibular Changes

Hicks (1978) found that there was little variation from the initial measurements, but does not show the measurements or discuss them. Cotton (1978) found in his animal experiments that the mandibular intermolar distance appeared to be affected by the increased width of the maxillary arch; increases ranged from 0.9 mm to 1.9 mm. Again we must allow for the abnormal expansion in these animals and these results may not be clinically relevant. Frank and Engel (1982) found an increase did occur during the expansion phase but that it was not statistically significant. This also proved true during their follow-up treatment.

3.4.6 Retention and Stability

Hicks (1978) varied the retention periods of his subjects, with one subject having fixed retention for 8 weeks, three patients had removable retainers, and one patient had no retention. He found that the skeletal increases were stable in the patient with fixed retention, while small skeletal decreases occurred with removable retainers. The patient with no retention lost 45% of his gain in the first 3 weeks and in a yearly follow-up had lost 69% of the initial expansion.

Cotton (1978) observed that a period of fixed retention appears desirable in order to maintain all the achieved midpalatal separation. Cotton (1978) and Hicks (1978) believed that in anticipation of dental relapse there is a need to overtreat. The problems of skeletal relapse and their stability with fixed retention is a controversial area and will be considered in greater detail in considering rapid expansion. Haas (1961),
Krebs (1964) and Thorne (1956, 1960) will offer conflicting opinions as to
the stability of the skeletal expansion. Cotton came to the conclusion that
even with slow expansion a period of fixed retention was advisable.

All the authors agree that some dental relapse is inevitable. Krebs
(1964) adds that even lengthy retention will not prevent some tooth
movement relapse. Hicks (1978) found that with removable retainers, since
all maxillae had been overexpanded, none of the patients returned to a
crossbite as a result of their relapse. The general conclusion from the
literature recommends overtreatment and a period of fixed retention,
probably eight weeks is sufficient.

Muguerza and Shapiro (1980) examined mucoperiosteal procedures on
monkeys using implants to evaluate relapse. The incision to reduce tension,
created by stretching of the palatal mucosa, was made through the palatal
gingiva down to the cortical bone parallel to the arch and approximately 3
mm from the teeth. It passed anteriorly through the primate space and
posteriorly it terminated distally to the last molar. The incisors were made
unilaterally so one side could be compared to the other. Using radiographs
and wires attached to buccal tubes similar to Cotton (1978), molar
angulation changes were evaluated and the implants revealed any bony
changes.

The conclusions reached by Muguerza and Shapiro were that this
procedure was not effective in reducing post-expansion relapse. As they
believed that the soft tissue tension is a significant factor in causing
relapse, they assumed that the fault must lie in the surgical procedure
performed. They also suspected that wound contraction on healing
subsequent to the formation of scar tissue contributed to the relapse. In
addition, they believed they should change the site of the incisions as the supracrestal gingival fibres, having been stretched through tipping of the teeth, may be more significant and an incision around the necks of the teeth may be more effective.

3.4.7 Discussion

This section representing the supporters of slow expansion should include the common criticisms of rapid expansion. Cotton (1978) in describing the rapid expansion techniques says they are designed to produce maximum transverse separation of the maxilla, while minimising concomitant tooth movement. It is paramount to produce immediate bone repositioning, decreasing the time available for tooth movement. Fixed and then removable retention is used for lengthy periods of time to allow for healing and reconstruction of sutural morphology.

Storey (1973) said that the rate of relapse with slow expansion was markedly reduced and histologically sutural integrity had been maintained. Storey hypothesised that slow expansion with continued growth of bony serrations within the suture produced the best form of retention with least relapse.

Cotton's second point of contention is based on Isaacson and Ingram (1964) who showed that each turn of the rapid expansion appliance produced forces of from 3 to 10 lbs which accumulated with successive turns to loads of more than 20 lbs. These authors questioned the need for such high loads. They suggested that an optimum rate of activation would be one whereby additional loads are added at close to the same rate as the facial skeleton can respond by physiological movement. This is further supported by Storey (1973) who believed that the production of a more mature form of bone
during the filling in process at the midpalatal suture is more stable. This will be discussed further when comparing rates of expansion in Chapter 5.

Cotton's third criticism of rapid expansion is that it is too traumatic in the initial response of the midpalatal suture. The initial histological findings on post-expansion have been a loss of sutural integrity with a change from highly organized to loose connective tissue. Other sequelae such as oedema, haemorrhage, and inflammatory responses are also undesirable. Histological studies from animal studies describe microfractures and free-floating islands of bone in the sutural ligaments. Here he quotes Melsen (1972) and Ohshima (1972) but in no case has it been demonstrated that it is beyond the physiologic capability of the experimental subjects to adapt to rapid expansion. The work of the authors quoted above will be considered in subsequent sections. Cotton comes to the conclusion that it may be more prudent to proceed with a longer period of slow expansion, a short period of fixed retention and no removable retention, than to use rapid expansion with a lengthy combined period of fixed and removable retention. Kutin and Hawes (1969) also conclude that in general terms both slow and rapid expansion procedures are effective. Both produce a repositioning of the maxillary alveolar process and a more buccal positioning of the maxillary teeth.

Again these conclusions are the same as Sims (1977), namely that the clinical results of the different procedures are similar apart from the rate of expansion and duration of retention involved. We should also keep in mind that these authors are discussing treatment in the mixed dentition period of mild to moderate posterior crossbites. Under these conditions the above authors, when comparing slow and rapid expansion, seem to favour slow expansion procedures as the technique of choice.


CHAPTER 4

RAPID MAXILLARY EXPANSION

4.1 Indications For and Against Rapid Maxillary Expansion

4.1.1 Indications for Rapid Maxillary Expansion

Haas (1980) lists six primary indications for rapid expansion.

(i) Cases of real or relative maxillary deficiency.

Real and relative deficiencies are defined in section 1.1. A real deficiency is characterized by compression of the maxilla when compared to the rest of the facial bones and the mandible. A relative deficiency exists when the maxilla appears to be normal when compared to adjacent structures and the mandible is oversized.

(ii) Cases of nasal stenosis.

These are characterized by full-time mouth breathing and a constricted nasal aperture with the conchae literally compressed against the septum.

(iii) All types of CI1II malocclusions.

Haas includes the pseudo CI1II, the dental CI1II, and the surgical CI1II. He feels that, the buccal crossbite can be corrected in the first 3 months, the anterior crossbite improved, as well as an improvement in the denture base relationships.

(iv) The mature cleft palate patient.

The procedure may not be particularly advantageous in the young cleft patient as they are very easy to expand with less complex methods.
(v) Anteroposterior maxillary deficiency cases.

Cases of negative ANB angles, negative Point A to facial plane or negative Wits analysis which would benefit from maxillary protraction. A prerequisite for such action would be rapid maxillary expansion to loosen the maxilla and facilitate the protraction.

(vi) Selected arch length problems.

In a mature good morphogenetic skeletal pattern or where selection of first or even second premolars would produce difficulties, as the profile is invariably flattened. There may be difficulty in closing extraction spaces and even greater difficulty in keeping them closed.

This list reflects most of the indications quoted for rapid expansion in the literature. Timms (1981) gives priority to the relief of nasal obstruction and includes in his medical indications, poor nasal airway, septal deformity, recurrent ear nasal and sinus infections, allergic rhinitis and asthma, and as a preliminary to rhinoplasty.

This creates the dilemma for the orthodontist of expanding the maxilla for medical reasons at the expense of the dental considerations. Timms feels that priority should be given to the medical indications.

McRacken (1970) said he "never felt justified in turning a normal occlusion into an abnormal one to influence nasal respiration". Brogan (1977b) also felt expansion is not indicated unless there is a definite cross-bite, and the patient is prepared to accept follow-up orthodontic treatment, as this will be critical in retaining the benefits obtained. Griffin (1978) felt
that normal occlusion was not a contraindication to treatment and that after expansion and retention for six weeks the teeth are permitted to resume their prior relationships. The nasal aspects of rapid expansion will be further considered in section 4.7.

Stockfish (1969) includes in his indications, constriction with protrusion without anterior crowding or with anterior spacing. Dipaolo (1970) notes that there is always an increase in lower face height with rapid maxillary expansion, which obviously in some cases will be most desirable. In the hyperdivergent pattern it will be undesirable and a depressing force must be applied against the buccal segments to prevent molar extrusion during expansion; that is, chin cups with vertical pull elastics. Haas (1961) states that "while this procedure is of benefit to CIII, pseudo CIII, cases of severe maxillary compression, and in patients with pronounced nasal insufficiency, it is by no means a complete treatment". Except in a few CII malocclusions with lateral discrepancies and occasionally in pseudo CIII malocclusions. It does expedite full treatment of other problems, in that it reduces the amount of tooth movement necessary when fixed appliances are placed. The expansion not only results in an increase in dental arch width and hence in total archlength, but also of equal importance, carries the attachment of the buccinator muscle laterally which makes judicious expansion of the mandible a safer proposition.

Haas (1970) divides the anteroposterior discrepancy into CIII division I, CIII open bite, and CIII closed bite and considers the appropriate treatment alternatives. Haas (1980) adds his belief that grossly deficient maxillae or overdeveloped mandibles are only manageable with surgery. However, if the circumstances of overdevelopment are only moderate one can lessen the effective mandibular length by producing a downward and backward
rotation of the mandible.

Vertical plane anomalies are characterized by heavy muscled, hyper-divergent, deep bite cases which are obviously benefitted by the bite opening effect of the downward and backward rotation of the mandible. The poorly muscled, hypodivergent, open bite pattern is still not a contra-indication since the bite opening can be resisted by the application of vertical pull headgear. Haas feels the width factor is the more important since it changes least with facial growth and stops growing the earliest. While it is impossible to ignore vertical and anteroposterior discrepancies, an attempt to correct the transverse discrepancy by moving teeth only, is invariably doomed to certain relapse.

Haas (1970) considering CIIII malocclusions felt that in CIIII closed bite skeletal patterns the expansion corrects the crossbite relationship by lateral and bending movements of the alveolar process. As a result of the accompanying downward and backward rotation of the mandible the effective length of the mandible is reduced and lower face height improves. The anterior crossbite is partially or completely corrected by the forward shift of the maxilla and the counter clockwise rotation of the mandible. If this correction is incomplete the addition of heavy CIIII elastic traction is utilized to complete the correction.

With a CIIII open bite skeletal pattern the patient is subjected to a vertical pull chin cup to counter the bite opening. Protraction spines can be added to this chin cup and elastics worn from the distal of the stabilized appliance. The direction of force is thus in a horizontal plane and while the chin cup will orthopedically influence the mandible in a forward and upward direction the elastics will pull the entire maxilla forward. CIIII cases
treated by palatal expansion and subsequent orthopedic influences have an improved facial balance over cases treated by conventional methods due to the changes in posture of the incisors in relation to their denture bases. Conventional treatment causes labial tipping of upper incisors anchored to a retruded denture base. Grossman (1970) supports Haas's findings on treatment of CIII discrepancies. He confirmed the forward movement of the maxilla cephalometrically allowing for simultaneous correction of anterior and posterior crossbites. He also adds that severe CIII malocclusions will probably require surgery. Biederman (1973) also advocates rapid expansion for marginal CIII cases allowing for the need for extraction or even surgery in severe cases. He also used similar treatment to Haas to improve anteroposterior corrections and improve or deepen the overbite. Haas suggests that in all cases point A moved forward and sometimes downward. Although this is supported by the cephalometric findings of Davis and Kronman (1969) it will be shown in section 4.3, when considering the cephalometric evaluation of the effects of rapid expansion, to be a point of contention with regard to its stability.

CIII division I skeletal cases demonstrate that the downward and forward movement of the maxilla makes the skeletal pattern worse and this could be further compromised in open bite cases. Haas (1970) found that the maxilla and mandible tended to return to their former positions. He then placed cervical traction and found that, not only was the maxillary growth inhibited, but the maxilla was retracted. Thus, while the mandible was free to grow downward and forward, the maxilla was restrained. In describing the effect of cervical headgear Haas (1980) felt that a force of approximately 32 to 48 ounces per side is not only sufficient to inhibit maxillary growth, but literally causes the maxilla to slide down and backwards on the undersurface of the cranial vault. The sutures of the
maxilla are so orientated as to readily permit such a dislocation. Haas recommends the use of extra oral traction in virtually all CIII and many CII cases. If the vertical dimension is ideal, a straight posterior thrust from cervical gear is favoured to restore the maxilla to its former position. In CIII patterns the headgear is continued to retract the maxilla beyond its former position. In the skeletal deep bite case, the outer bow is bent at a higher level to tip the maxilla downward in back to hopefully produce downward and backward rotation of the maxilla. In the open bite skeletal type a high pull or vertical pull is indicated. Here the primary objective is interference with the descent of the maxilla. While not seriously considering the effects of extra oral force Haas felt that the restriction of forward growth was counteracted by an increase in vertical growth, so that the overall growth potential is not changed, only its direction.

4.1.2 Contraindications for Maxillary Expansion

Timms (1981) suggests there are very few but lists several possibilities.

(i) Sutural patency is essential for rapid expansion. This would set an age limit at synostosis of the midpalatal suture. As suggested in section 3.4 this is extremely variable and Timms adds that with the aid of an oral surgeon this limitation can be eliminated.

(ii) The presence of a normal occlusion in the lateral aspects. Again Timms believes the overriding medical reasons of a respiratory nature have a higher priority and should be accepted by the orthodontist as a challenge.

(iii) The tendency to open the bite caused by the mandibular rotation. Timms felt that this is minimised by the use of cap splints.
Whereas, the use of a banded appliance increases the effect of
this extrusion, the splints distribute the force more evenly
throughout the maxillary complex and minimise this effect.
Certainly Haas does not consider this a contraindication but
something that has to be controlled by additional therapy. A
study by Linder Aronson (1979) found that long term analysis of
rapid expansion resulted in no changes in overbite.

(iv) Timms felt that crowding, as such, is not a contraindication to
rapid maxillary expansion but there is little additional space
gained. Timms also felt that you should consider the extent of
the crossbite and if it involves the lateral incisors you may get
additional arch length improvement.

(v) The only real stumbling block to rapid expansion is retention of
the appliance. The large forces used in rapid expansion are
lateral and tend to unseat the appliance. The bulk of these
retention problems occur in younger patients where the truncated
shape of the deciduous teeth and the newly erupted first
permanent molar do not provide enough retention for the
appliance. The writer encountered this problem in one of his own
children and from discussion with P. Lewis (1983) felt that this is
not an uncommon clinical problem. Fortunately this is offset by
the fact that the resistance to maxillary separation is often
reduced in this group and thus not a frequent problem.

Haas (1973) in response to other suggested contraindications suggested
that:
- It is impossible to create a nasal obstruction with maxillary expansion.

- If a partial or complete cleft appears following expansion then it was in existence before the palatal expansion.

- In his experience rapid expansion has never devitalised a sound tooth, and that this is of no concern with his maximum anchorage appliance and of little concern with an all-wire framework appliance.

- Haas felt that dizziness, poor vision, nausea, and other associated problems are mainly psychological and induced by the orthodontist. He suggests avoiding references to "splitting" or making the treatment sound extraordinary.

- Root resorption is considered more fully in section 4.5 but Haas states "I cannot recall a single incident of root resorption of teeth acted upon by the maximum anchorage appliance." This will be shown to be not strictly true but probably due to subsequent repair has not been of clinical significance. Timms (1981) also felt the problem is selfcorrecting.

4.1.3 Hazards Associated with Rapid Expansion

Wertz (1970) suggests the precaution of applying this process to only bilateral narrowness, and avoid its use in all but very mild unilateral cases. Expansion of a unilateral constriction may cause the mandible to deviate to the non-narrowed side by following the dictates of the dental cusps. This may produce a permanently displaced mandibular position and eventual joint disturbances. This is not to be confused with the unilateral clinical crossbite that is accompanied by mandibular displacement. Wertz also noted that while rapid expansion is described as a bilateral expansion, the skeletal effect in some cases is more pronounced on one side than the other. This may be due to individual skeletal architecture being such that
articulations of the maxilla on one side are more rigid than those on the opposite side. A third precaution suggested by Wertz is that we should do the expansion on its own and then on completion of the suture opening and stabilization the clinician can initiate other procedures. This avoids misinterpreting symptoms such as pain as being due to problems with the expansion, when they are due to the associated treatment procedures.

Timms (1981) includes in his hazards:

- Oral hygiene problems: This is a significant argument in favour of the all wire framework appliance.

- The length of fixed retention being up to four months. The palate becomes spongy and haemorrhagic. Timms found that it recovers quickly, however, and that even hypertrophic tissue around the edges of the appliance disappears without treatment.

- Dislodgement and breakage: If the appliance becomes loose on one side only, the loss of rigidity allows the basal bone to relapse. The correction for this is to turn back the screw, recement the appliance, and resume the expansion. Breakage is rare and usually involves the screw. Again it may be necessary to remove the appliance, remake it, and recommence the expansion therapy. This is used as a criticism of the split acrylic appliance, if it is broken or warped the acrylic portion may cause major trauma to the palatal mucosa and even the underlying structures.

- Infection: An invasion by pathogenic organisms represents a true hazard in rapid expansion. Beneath the appliance, organisms can flourish in perfect incubation conditions. In this event the appliance must be removed and cleaned and the expansion recommenced once the condition has cleared up.
- Failure of the suture to open: Pain caused by the failure of the suture to open or general faciomaxillary rigidity. Both these problems are associated with increasing age and should be followed by cessation of the expansion procedure. Extensive damage can be done if expansion is carried out against an unyielding suture and the appliance is driven into the alveolus. On no account should expansion be continued for more than one week against a suture that has not opened.

4.1.4 Timing of Treatment

These aspects have been considered in section 1.3. Regarding the arguments in favour of early treatment, Haas (1973) favoured the late mixed dentition stage. He waits for the eruption of the first permanent molar to provide anchorage for the appliance, yet still has growth potential, the ability to correct functional problems before permanent deformation occurs, eliminate temporomandibular joint problems, create a more favourable environment for the tongue, and facilitate reduction of mouth breathing problems. Haas found patients more manageable at 8 to 10 years of age, but agrees that there are advantages associated with the pubertal growth spurt. Haas concluded that there was a degree of leeway in the most appropriate timing of treatment which extended between 5 to 14 years of age. This upper limit, he also admits, is rather arbitrary, and as long as the suture remained patent he believed rapid expansion with suture splitting is possible. As shown in section 2.4, Persson and Thilander (1979) felt rapid expansion should be effective up to 20 years of age although they allow for large individual variation. We must also allow for Isaacson and Ingram (1964) and Wertz (1970) who believed that the resistance due to circum-maxillary structures is the critical factor, and this will significantly affect the variability of the effectiveness of rapid expansion over 15 years of age.
Timms (1981) retains an open mind on age limits and relies on the presence or absence of pain, and the availability of oral surgery to assist in achieving expansion if necessary. Haas (1973) reports successful opening of the suture in a 38 year old male. Other authors - Stockfish (1969), Wertz (1970) and Brogan (1977b) - reported success in opening the suture in patients over 20 years of age. Freijrs (1981) concluded that 18 years of age is a reasonable time to expect success. The impression I have gained from conversations with private practitioners is that this is a little high and that, being more conservative, they tend to favour the 15 year old limit to avoid complications. They then tend to change to a slower activation rate rather than risk the possibility of forcing a bicuspid through the buccal cortical plate or consider the alternatives of oral surgery.

Cleall et al. (1965) state that "in the mixed dentition, the active growth period was associated with rapid reactions of the sutures to the expansion appliance". They add, however, that the immaturity of the suture at this time may allow more rapid breakdown and return towards normal unless retention is prolonged. Melsen (1975) found that, true stimulation of sutural growth was only found in children who had not attained pubertal age. In older patients expansion was attained by numerous microfractures in the suture region. The post-traumatic reaction around these fractures was significant, for during the course of healing, bridge formation between the two halves of the maxilla were seen preventing further growth at the suture from taking place. This may not be significantly detrimental in that any further growth would be minimal.

Brin et al. (1981) using rapid expansion in cats, examined the effects of age on sutural cyclic nucleotides. They felt that the differing responses of younger and older cats to the expansion force were due to variations in
cellular biology, while in the younger animals the tensile force resulted in an increase in the staining intensity of cyclic nucleotides of the osteoprogenitor cells. The response in the older animals was characterized by a reduction in nucleotide staining intensity. Moreover the younger animals presented layers of newly calcified bony matrix at the edges of the expanded suture, while the sections from the older animals were either devoid or only displayed minute amounts of new bone formation. These results demonstrate a decline in the cellular activity of the older cats to respond to the mechanical stimuli. This could be significant in the relapse potential of rapid expansion techniques in older patients and is discussed further in Chapter 5.

4.2 Appliances Used in Rapid Maxillary Expansion

4.2.1 Screw Appliances

These can be divided into two basic groups: the all-wire framework appliance and the split acrylic group. These groups could be further subdivided into those that use bands as attachments to the teeth and those that use cast splints.


Haas (1961) described the technique for construction of his appliance (Fig. 4.1). He selects bands for the first permanent molars and either the first premolars or first deciduous molars. Using an alginate impression he
transfers these bands to a working model. Buccal and lingual bars are placed as close to the gingiva as possible and contoured for maximum contact with the abutment bands and unbanded teeth. The solder joints are as large as possible to additionally strengthen the anchor units. Haas feels it would be desirable to band more teeth. However, the difficulties created with the path of insertion prevents this. Timms (1981) uses cap splints to incorporate as many teeth as possible to distribute the load over the entire alveolar length and reduces the load on individual teeth. The utilization of more teeth with splints not only reduces the tipping effect, but in Timms' opinion, reduces the tendency for extrusion during expansion, and thus reduces the bite opening effect. Wertz (1970) felt that as the buccal bar is non-stress-bearing it could be omitted as it only makes the appliance more difficult to seat. Haas (1970) felt that omitting the buccal soldered bar

Fig. 4.1 Haas type split acrylic appliance
Timms (1981)
invites more dental displacement and less suture opening. Timms does concede that in some instances bands are superior to splints in view of their closer adaptation and ability to be pressed into the gingival folds.

Haas continues, that the lingual bars are extended anteriorly and posteriorly sometimes to include the canines and/or second molars. They are directed palatally to act as lugs to anchor the bands and bars to the acrylic portion. The acrylic masses are confined to the rather ischemic tissue which lies between the first premolars and the first molars. Care must be taken to avoid impingement on the tissues that possess a rich blood supply, normally the rugae, the gingival tissue, and the tissue overlying the greater palatine foramen. Haas (1973) adds that 3 to 4 millimeters should be relieved from the superior aspect to accommodate any dropping of the palatal shelves that may occur. The entire periphery is given a generous 2 to 3 millimeter bevel particularly at line angles and corners. Under no circumstances should the acrylic be relieved from that portion of the button which contacts the ischemic tissue of the inclined portions of the palatal vault and lingual alveolar process. Isaacson and Murphy (1964) describe the anchorage units involved as, the buccal teeth, the periodontal fibres, the walls of the palatal vault and lingual alveolar bone, and the buccal alveolar process. The efficiency of this appliance over the all-wire framework is more evident in older patients where the resistance to midpalatal suture opening will be greater.

Other types of split acrylic appliances described by Timms (1981) are the Derichsweiler type; tags are welded to the palatal aspects to provide attachments for the acrylic which is also extended to the palatal aspects of all non-banded teeth. Timms describes in detail his cap splint appliance (Fig. 4.2A). He modifies this in the deciduous and early mixed dentitions by
Fig. 4.2 Timms' cap splint appliance

A) With palatal acrylic as used in the permanent dentition
B) Without acrylic for deciduous and early mixed dentitions.

Timms (1981)
leaving out the acrylic portion. He felt that this is preferable in younger children as it has better hygiene properties and permits a longer period of retention (Fig. 4.2B).

Howard (1969) described an appliance to overcome loss of expansion during screw replacement. He used cap splints with the screw attached by fracture locating plates. By undoing the screws of the locating plates the expansion screw can be removed, another impression taken, and a larger screw fitted. While this is not strictly a split acrylic appliance, the cap splints provide greater anchorage than the all wire framework appliance with bands.

Cohen and Silverman (1973) avoided bands altogether, utilizing the direct bonding technique. A reinforcing wire, adapted to the lingual aspect of the buccal teeth and joined to the jackscrew, was covered along with the buccal, occlusal, and lingual aspects of the teeth with cold cure acrylic. This was then bonded to the buccal teeth with the "Nuvaseal bonding system". It is then adjusted as is any normal appliance.

The all-wire framework appliance is constructed in a similar manner, but leaving out the acrylic portion (Fig. 4.3). Melsen (1972), Biederman (1973) and Linder Aronson and Lindgren (1979) used an expansion screw straight across the palate (Fig. 4.3b). Timms (1981) adds the Isaacson type which incorporated a Minne expander or spring-loaded screw instead of the normal expansion screw. Biederman (1973) extended a lingual strut if the deciduous molars showed signs of root resorption. Sain (1973) described the hyrax screw which he made even simpler by only banding the first permanent molars. He used to place the screw as high as possible, but as these patients do not usually place their tongue up into the vault of the
Fig. 4.3 a) The All Wire Framework Appliance used by Biedermann uses a special screw either Hyrax (Dentaurum 602-813), Leone 620 or Unitek 440-160 (has incorporated a method for replacing the screw. (Timms 1981)

palate he now goes straight across. He also used to place a lingual bar extending up to the canines and back to the second molars, but found this unnecessary. He found the lingual acrylic too irritating to the palate and had to allow a recovery time before placing the retainer. He now leaves the hyrax appliance as a fixed retainer for three months and does not place any further retention but closely watches patients over the next 6 to 8 weeks or if it is a severe case or needs further treatment may continue with the fixed retainer. McCracken (1970) also found the hyrax screw more hygienic than the split acrylic appliance; he too omitted banding the bicuspids if the path of insertion so dictates. He admits cast splints are more certain and reliable, but require the use of skilled technicians, considerable laboratory time, and thus additional expense.

The Unitek catalogue (119, 1984) describes a two-stage expansion screw. The widening of the maxilla by palatal expansion is described as often requiring two different expansion screw appliances. The Unitek Two-Stage Expansion Screw accomplishes palatal expansion up to 14 mm with a single appliance. It is small enough in the first stage to fit comfortably in a narrow maxillary arch, expansion up to 7 mm can be executed. Then by simply replacing the central screw with a longer one for second stage expansion, the arch can be widened another 7 mm.

The advantages of the split acrylic appliance according to Haas (1970) are:

- It results in greater nasal cavity and apical base gains. Wertz (1968) used an all-wire framework appliance which produced less changes in nasal cavity width. Haas felt that there would have been a much more favourable result with "a maximum anchorage appliance".
- It results in a more favourable relationship of the denture bases and
frequently in the anteroposterior directions as well.

- It creates more mobility in the maxilla, for continued orthopedic influence.

Responding to common criticisms of the split acrylic appliance, Haas (1970) felt that, if properly designed with smoothed rounded edges and care is taken to confine the acrylic to the ischemic tissue area of the palatal walls and alveolar bone, tissue irritation is not a problem. Haas also felt, on the subject of hygiene, that the tongue is unwittingly a "superb janitor". There is no greater incidence of halitosis with the acrylic appliance than with the conventional appliance. Timms (1981) concedes that there is a hygiene problem and a risk of infection. However, Timms states that the hyrax screw appliance has too much flexibility, he stresses that cap splints are the primary agents of rigidity and that the acrylic is only a connecting agent but is of significance.

Scott (1982) compared the effects of an acrylic-free and an acrylic reinforced appliance for their effects on the cross-sectional area of the palate. His results suggest that there was little difference between the two appliances and concluded that the reinforced appliance does not give greater expansion of the palatal vault than the acrylic-free appliance. Ohshima (1972) used two appliances on Rhesus monkeys at different rates. A split acrylic plate and an all wire framework appliance. The appliances were expanded for ten days twice per day. His results indicated that the animals expanded with the split acrylic appliance actually expanded less than those with the all-wire framework and that there was less evidence of trauma. Ohshima puts these differences down to individual anatomy rather than the appliance used.
Thus Scott (1982) and Ohshima suggest that in relation to expansion achieved the differences between the two basic types of rapid expansion appliances may not be as significant as Haas and Timms indicate. Wertz (1970) felt that while the all-wire framework appliances can open the suture, without the acrylic portion there may be more significant relapse. The studies of Zimring and Isaacson (1965), discussed in Chapter 5, demonstrated forces being present after expansion that tended to collapse the expanded arch for a period of 5 to 7 weeks. If the maxillary base is stable and an expanding force is directed to the buccal teeth, most would agree that at some stage the teeth will move laterally through the bone. If we reverse the activation and stabilise the teeth in the unstable separated maxilla and there exists a force to the maxillae that would move them toward each other, we can figuratively see the maxilla moving through the stabilized teeth. This would result in partial relapse of the basal expansion and nasal cavity expansion. This cannot occur with the acrylic appliance where the acrylic buttons support the maxillary base.

Another issue raised by Barber (1978) is that the wire and acrylic appliances do not cause substantial redirection of expansion forces against the palatal mucosa. If they did, ischemic necrosis and sloughing of the mucosal tissue adjacent to the palatal acrylic buttons would be expected. This is clearly not the case and Barber therefore suggests that with either appliance design the brunt of the expansion force is borne by the thin plate of alveolar bone buccal to the anchor teeth. Barber's suggestion also seems to be erroneous. Earlier, Isaacson and Murphy (1964) describe the anchorage units involved as, the buccal teeth, the periodontal fibres, the walls of the palatal vault and lingual alveolar bone, and the buccal alveolar process. The initial resistance to the expansion is provided by the hyalinization reaction involving the periodontal membrane and roots of the teeth. These
pressures are then transmitted via alveolar stresses, produced by deformation of the alveolar process, to the other components of the alveolar process mentioned by Isaacson and Murphy, of which, the buccal cortical plate is an integral part.

Another situation described by Haas (1980) where the acrylic may be of more significance, is where the suture fails to open and activation is changed to a slower rate. It was noticed by Haas that the tissue-borne appliance acts not only against the dental anchorage, but also against the inclined walls of the alveolar process, lingual alveolar plate, and deeper alveolar structures. The striking change in morphology of the palatal vault Haas attributes to the heavy forces delivered by the acrylic buttons compressing the palatine arteries. This in turn stimulates the connective tissue surrounding the vessels to differentiate into osteoclasts to remove the underlying bone and thus protect these arteries from injury. In so doing the vault is hollowed out and a true apical base expansion is induced. This conjecture by Haas should be viewed with caution in that at this age we would expect very little alveolar change and mostly dental tipping to achieve crossbite correction. It may be possible that there is a narrowing of the alveolar base from the palatal side without significant basal expansion. Perhaps this aspect should be reviewed by the reader after consideration of the discussion presented in Chapter 5 on the resolution of induced stresses and strains being the primary cause of changes in bony structures.

4.2.2 Alternative Expansion Devices

Haas (1961) describing removable appliances felt that the horizontal force of the screw against the inclined lateral walls of the palate would tend to displace the appliance, and that if maximal suture opening is to be
achieved the appliance must be fixed. Also the removable appliance would probably tip teeth rather than move them bodily. Timms (1981) also felt that forces were too high for removable appliances to be effective. Isaacson and Ingram (1964) also discounted the use of removable appliances for this type of procedure. They also felt that with the high level of force encountered during activation, plus the presence of high residual loads, makes the value of screw appliances incorporating a spring loaded expansion screw extremely doubtful. On the contrary, in their experience the loads produced served only to reduce the expansion capabilities of the appliance and necessitate remaking the appliance to achieve the expansion desired. Chaconas and Caputo (1982) also support this in finding the Minne expander significantly less efficient than the conventional screw appliances.

It is interesting to note that Griffin and McGrath (1978) felt that removable appliances, with adequate retention, can be used effectively for rapid maxillary expansion. K. Godfrey (1984) also found from personal observation that, with adequate retention and two quarter turns per day, removable appliances could achieve rapid maxillary expansion.

4.2.3 Activation of the Appliance

Haas (1961) writes that most screws are calibrated to give 0.8 to 1.0 mm expansion for each full turn of the screw, being constructed so that they are turned a quarter turn at a time. At insertion Haas recommends one full turn of the screw over a period of fifteen minutes, allowing the parent, by way of instruction, to make the final turn. The parent is then instructed to turn the screw a quarter turn each morning and evening. The patient is observed at 7, 10, 14, 18, and 21 day intervals and screw manipulation discontinued when sufficient expansion has been achieved. Haas recommends significant overtreatment to allow for subsequent
uprighting of tipped teeth and recontouring of bent alveolar processes. To prevent the screw turning back, it is stabilized on the same day that activation is stopped with either cold cure acrylic or brass wire. This is very similar to the method described by Wertz (1970).

Timms (1981) stresses the importance of patient instruction. The principles should be carefully explained to the parent as their assistance is required in activation. "The appliance will make the upper jaw wider, but probably not noticeably so. The widening increases the nasal airway and makes breathing easier." It should also be explained that a space will appear between the front teeth, but this only indicates the success of the treatment and will correct itself without further treatment. Difficulties of speech and mastication should also be mentioned together with points of oral hygiene.

Timms divides his activation schedule into three age categories:

- Up to 15 years of age: turn 2 turns morning and evening to produce one full turn per day.
- 15 to 20 years: increasing resistance caused by higher force build up may cause pain with the above activation. Timms then changes it to four quarter turns spread evenly throughout the day.
- Over 20 years of age: The substantial build-up of forces now means that you may not be able to get more than two turns per day. Over 25 years of age the suture is often opened surgically and it may not be necessary to reduce the activation.

A return visit should be organised after one week in the younger age group, but after 3 to 4 days in the older age groups to allow closer
monitoring to review any indicators of suture opening, lack of suture opening, or significance of pain.

Haas (1980) adds that on occasions he has activated more rapidly but cannot recommend it as a general rule. Also if in an older patient the forces created are not dissipated, because the suture fails to open, he stops activation for the present and turns back until the appliance is comfortable. Then he reactivates at whatever rate is consistent with comfort, with the intention of gaining slow expansion.

Dipaolo (1970) repeats that it is normal to activate twice per day but there are exceptions. He feels separation rarely occurs over 16 years of age due to increasing skeletal resistance. Operators advocating 8 to 10 turns per day are dangerous because of individual variations in cases of suture opening. Severe symptoms may appear such as, blurring of vision, dizziness, headaches, nose bleeds, or pain in the zygomatic area and bridge of the nose. At the first signs of pain re-evaluate treatment, stop activation for a period of time and determine if the suture is opening. Wertz (1970) also suggests this and adds that reduction of the activation schedule has proved most successful providing time for cellular adjustments to occur at the activation sites. He concedes that the reduction of activation probably allows for more extrusion of teeth, bending of the alveolar process, and orthodontic tooth movement. Thus the skeletal repositioning will probably be less than desired.

To continue the note of caution on expansion rates, we should recall the clinical advice of Isaacson and Ingram (1964) as to activation. They felt that more than two activations at insertion caused too great a force build-up. In younger patients, twice daily activations for 4 to 5 days, then
once daily for the remainder of treatment. In older patients, twice daily for the first two days, then once daily for 5 to 7 days, then one every other day until the end of treatment is their suggested activation rate.

**How much to expand**

As will be pointed out in the consideration of retention and relapse, all the authors in the literature accept that the orthodontic portion of the expansion achieved will partly relapse. Krebs (1964), Stockfish (1969), Timms (1976), and Linder Aronson and Lindgren (1979) show that between a third and a half of the expansion was lost before stability was reached. Thus the clinician must resign himself to the inevitability of some relapse and allow for it by overexpansion during treatment.

Timms (1981) felt that "If the maxillary teeth are expanded to lie completely buccal to the mandibular teeth, they may lock cuspally in this position and be difficult to correct''. A convenient guideline is to stop when the maxillary palatal cusps are level with the buccal cusps of the mandibular teeth.

Haas (1965) recommended that most cases should be expanded until the maxillary arch completely enclosed the mandibular arch. This made allowance for bending of alveolar bone and subsequent uprighting of teeth. Haas (1980) states, "I feel that most operators do not carry the expansion far enough. Furthermore, it is more accurate to measure the exposed thread with a divider and transpose this measurement to a millimeter rule to determine the amount of expansion". Haas continues that he never expands less than 10 mm and usually 10.5 mm up to 14 mm. Timms (1981) also stresses the importance of knowing how much of the screw is left. "Do not let the two halves of the appliance disengage or relapse and perhaps
other traumatic injury problems will eventuate; for example, acrylic embedding in the palatal mucosa". Haas (1970) repeats this recommendation. He found that when the midpalatal suture opens, the alveolar processes appear to bend laterally, while the palatal shelves drop inferiorly. This along with periodontal membrane compression results in considerable changes in the axial inclinations of the posterior teeth. It therefore becomes important that the dental expansion is overdone in the interest of improving the denture, base relationships. Correction of the dental crossbite alone is inconsistent with the primary objective of orthopedic treatment which is the establishment of a more favourable denture base relationship. For this to occur there must be marked overexpansion because the increment of dental arch width gained by alveolar bending, periodontal membrane compression, and extrusive tooth movement is almost certain to be lost.

The discussion of basal bone, alveolar bone, and dental movements during rapid expansion occurs below but there will be further consideration of these bony movements and their stability in Chapter 5.

4.3 Bony and Dental Movements During Rapid Maxillary Expansion

Haas (1970) describes the predictable phenomena associated with rapid maxillary expansion as,

(i) Anteroposteriorly, the opening of the midpalatal suture is parallel, inferosuperiorly the opening is triangular with the apex in the nasal cavity.

(ii) The central incisors react as expected, considering that they are linked by elastic transseptal fibres. As the suture opens, the
crowns converge, while the roots diverge. When the crowns come into contact, the continued pull of the fibres causes the roots to converge toward their original axial inclination.

(iii) The alveolar processes bend and move laterally with the maxilla, while the palatal processes swing inferiorly at their free margins. The effect is a dental arch expansion and an increase in intra nasal capacity.

(iv) When the midpalatal suture opens, the maxilla always moves forward and downward. This is probably due to the disposition of the maxillocranial sutures. Haas quotes Sicher (1947) as describing these sutures as being orientated in such a manner that growth would produce a downward and forward vector of maxillary movement. Since these "hafting zone sutures" are disengaged by the palatal expansion procedure, an effect similar to immediate growth is manifested in a downward and forward displacement of the maxilla.

(v) The change in maxillary posture invariably causes a downward and backward rotation of the mandible which decreases the effective length of the mandible and increases the vertical dimension of the lower face.

To compare the views of other authors who support or disagree with Haas, it is necessary to divide these overall movements into three planes:

The frontal plane; as commonly demonstrated on antero-posterior radiographs.

The transverse plane; as shown by occlusal radiographs.

The sagittal plane as shown by lateral cephalometric radiographs.
Further comparisons are made on pre-treatment and post-treatment dental casts, animal studies, and dry skull material. The majority of authors also compare effects immediately following expansion when the appliance is stabilized, then again following a period of fixed retention when the appliance is removed. Consideration of relapse effects are included in later sections. It should be pointed out that the scope and application of animal studies is limited. Timms (1981) considers that, the variations in morphology, and the effect of turning a normal condition into an abnormal one, should be kept in mind. This then minimises his references to animal studies and he gives far more weight to the clinical ones.

4.3.1 The Frontal Plane

(i) The central incisors

The majority of authors quoted discuss the appearance of a superior median diastema during the activation phase of expansion. Haas (1961) and Wertz (1970) offer explanations of this movement.

Haas (1961) describes this distance as about half the distance the screw has been opened. However, during manipulation the roots diverge a greater distance than do the crowns. After screw manipulation has ceased, the roots continue to diverge while the crowns tip towards the midline. After the crowns have drifted together the roots begin to move medially so that the incisors eventually resumed their original, or better, axial inclination. The entire cycle was completed in four to six months even with incisors spaced as much as 8 mm after appliance manipulation. Isaacson and Ingram (1964) found that the opening between the central incisors appears after 9 to 12 activations. Clinically I have found that it may not appear until the second week of activation, which may be slightly later than this. These
general observations of incisor movement are supported by Thorne (1956), Korkhaus (1960) and Rinderer (1966).

Haas (1961) quotes Brodie (1954) as hypothesising that orthodontic therapy can cause tensions in remote parts of the bone. Brodie labelled the source of some of these forces as transseptal fibres which he visualised as an integrated chain of periodontal like fibres linking all the teeth in the dental arch. Provenza (1964, p.333) describes transseptal fibres as collagen bundles running horizontally from the cementum of one tooth directly to the cementum of the adjacent tooth (Fig. 4.4). In their straight path, the fibres pass superiorly to the crest of the alveolus. These are massive bundles which serve functionally to unite adjacent teeth and support the interproximal gingiva. Osborne and Ten Cate (1976, p.131) found that, in addition to transseptal fibres, gingival fibres have been described as running from one tooth to another, as have ligament fibres passing through septal bone and it is likely that some of these fibres are also responsible for movement of teeth to maintain approximal contact. Ten Cate (1980, p.283) says that support for the concept of transseptal fibres drawing neighbouring teeth together to maintain them in contact is shown by the fact that relapse of orthodontically moved teeth is much reduced if a gingivectomy removing the transseptal ligament is performed.

Assuming the existence of these transseptal fibres, the action of the central incisors can be explained by, according to Haas (1961)

- As the maxillae separate, the crowns of the central incisors begin to move laterally and the transseptal fibres across the midline begin to stretch.

- The pull of the transseptal fibres causes the crowns of the incisors
Fig. 4.4 Mesiodistal Section showing Transseptal Fibres.
E, enamel space; IG, interproximal gingiva; CEJ, cemento-enamel junction; D, dentine; T, transseptal fibres; CA, crest of the alveolus; C, cementum; PL, periodontal ligament; A, interdental artery.

(Provenza, 1964)

to start tipping medially while the roots continue to diverge laterally with the fulcrum of their action being around the middle third of the root. After appliance stabilization, the continued action of these fibres causes the crowns to tip very rapidly toward the midline with the roots moving almost as fast laterally with the fulcrum of the movement being closer to the apex of the root.

- When the crowns approximate, the leverage changes, as the contact point of the crowns now becomes the fulcrum and the forces of the
transseptal fibres causes the roots to move medially towards their original positions (Fig. 4.3).

Haas (1961) and Thorne (1956) also point out that incisor separation is not an ideal barometer as to the amount of sutural opening. Since the incisors move at an astonishing rate, and their movement will commence as soon as separation commences, if the expansion rate is slow enough, it is possible for a diastema not to appear at all.

Wertz (1970) found that the maxillary incisors consistently upright and/or drop posteriorly during the period of stabilization. He feels this helps to describe the mechanism by which increased arch length is dissipated. The widening of the arch posteriorly must occur at the expense of the muscular ring formed by the superior constrictor, buccinator group of muscles. This creates more pressure on the labial surfaces of the maxillary incisors and aids in closure of the anterior diastema, but also displaces the incisors lingually. Wertz also found that at the completion of expansion the maxillary incisors tended to be routinely elongated relative to the SN plane. This reaction seemed to be independent of the effects on the palatal plane. The predominant movement was one of uprighting, so that the SN to upper incisal angle was decreased. At appliance removal the most significant finding was the tendency for the upper incisor to have dropped back. Rinderer (1966) comments that in some CIII cases with spontaneous correction of the inverted overbite of the front teeth, he found an increase in the labial inclination of the upper incisors. He believed, however, that there was a functional mesial occlusion in the original condition that led to the altered axial inclination of the upper anteriors. Once this was removed the incisors resumed a more normal inclination.
Fig. 4.5  These tracings show the action of the central incisors. Note how the angle of inclination of the incisors changed +13 degrees to -9 degrees in just twenty nine days. In another fifty three days it changed back to +9.5 degrees.

(Haas, 1961)

In general Wertz (1970) supported by Cleall (1974) felt that there was little overall increase in the arch length and that expansion should not be considered an alternative to extraction in any but very mild cases. In a further comment Wertz suggests that if a diastema is present prior to expansion, then it will return to this dimension or close more following expansion. Timms (1981) makes the point that mineralization of the suture may be incomplete during the spontaneous closure of the suture and consequently the teeth may become slightly loose and tender to percussion.
He further points out that severance of the transseptal fibres immediately post-expansion will result in non-closure of the diastema.

(ii) Molar extrusion

An extrusive component is frequently mentioned, in the literature, in association with rapid maxillary expansion. Stockfish (1969) considered molar extrusion contributed to the bite opening effect. He used a lateral bite plate on the occlusal surfaces of the premolars and molars in an attempt to reduce this opening effect, and if necessary followed it up with full band treatment. Grossman (1970) also felt that molar extrusion contributed to the bite opening tendency. He felt that this extrusion increases the vertical dimension, which in turn increases the backward rotation of the mandible to a downward and distal position.

Wertz (1970) also mentions alveolar bending and extrusion of the molar teeth. Wertz and Dreskin (1977) found that there was a 1 mm descent or extrusion of the molar teeth. Subtelny (1980) also felt it was important to prevent supra-eruption of molar teeth, with the ensuing downward and backward repositioning of the mandible in vertical developmental patterns. He also used a posterior bite block designed to exceed the freeway space. Its action is then additionally designed to depress or at least prevent eruption of the mandibular molars.

Timms (1981) felt that the use of splints instead of bands, and the incorporation of additional teeth minimised this effect. Timms also felt that after initial activation, the teeth move laterally apart within their respective maxilla. Since this movement is basically rotational, the teeth will gradually increase their buccal angulation to a degree conditioned by the rigidity of the appliance. There will eventually arise a considerable
component of force along the long axis of the teeth resulting in a slight extrusion of the anchor teeth. He quotes Byrum (1971) to support this concept.

(iii) Gross Bony and Dental Effects in the Frontal Plane

Thorne (1956) states that facial tipping of the molars and premolars has been established during expansion techniques. After removal of the appliance the teeth have in most cases tilted back in a lingual direction. Thorne and later Rinderer (1966) describe a method of assessing tipping of the teeth as a modified method of Chateau (1950). Models sectioned at the molars to lie on graph paper, had caps with long metal pins introduced perpendicular to their occlusal surfaces. These caps were transferred to models taken post-treatment and retention. Lines drawn on the graph paper corresponding to the metal pins for each model met at an angle. These angles indicated the amount of tipping which had occurred during treatment.

Cleall et al. (1965), Starnbach et al. (1966), Murry and Cleall (1971) using Macaca rhesus monkeys investigating sutural changes (discussed in section 4.4) and the nature of tooth movement resulting from rapid maxillary expansion found that, the histological reactions around the teeth did not indicate tipping of the teeth within the alveolus during the first two weeks of expansion, provided adjustments occurred in the adjacent sutures. It seemed that the palatal process, alveolar process, and teeth rotated outwards. This results in the palatal vault becoming flattened and the buccal teeth appear to have been tipped laterally.

Starnbach et al. (1966) subjected their sections to an angular analysis. Lines were drawn representing the palatal planes of each maxilla and the long axis of the buccal teeth. Variations in the angles formed by these
lines would identify rotations of the palatal plane around a vertical axis through the midpalatal suture. In addition the relationships of the axial inclinations of the buccal teeth to the palatal plane would indicate whether tooth movement was tipping or bodily in nature. Their results show that initial tooth movement was found to be bodily in nature supporting the lack of tipping evidenced by their histological investigation. The analysis of the angle between the buccal teeth and palatal process showed no significant differences between the control and experimental animals.

Cleall (1974), describing clinical changes, summarised the tilting effect by saying "Teeth in the buccal segments undergo a considerable amount of tipping. There is minimal effect in terms of actual tooth movement, however, the buccal rotation of the whole alveolus and the lowering of the palatal process of the maxilla result in the abnormal inclination of the buccal teeth. They upright either through forces of occlusion, or conventional root torquing". Thus the whole complex has rotated about a vertical axis through the midpalatal suture, allowing the buccal segments to swing laterally despite the tooth movement being bodily in nature.

Haas (1961) used serial frontal cephalograms to analyse the bony movements in the frontal plane. Haas adds "The shortcomings of making linear measurements from radiographs are realised. However, the measurements are being taken near the midline, so avoiding radiographic distortions. They are also remarkably consistent within the series. Thus the results have value on a relative, rather than an absolute basis, which is all that is intended".

Haas describing the effects in his clinical study, felt that the earliest gross reaction is a lateral bending of the alveolar process (discussed in
Chapter 5), followed by a gradual opening of the midpalatal suture. The palatal processes of the maxilla then begin to move inferiorly at their free margins to cause a lowering of the palatal vault.

It is worth noting that Griffin (1958) was describing this lowering of the palatal vault with resultant creation of tension in the septomaxillary ligament to cause straightening of the deviated nasal septum in the treatment of chronic nasal obstructions.

Haas goes on to describe the radiographs as showing a void extending from the medial incisal edge of the central incisor, superiorly through the articulation of the palatal crests of the maxilla and vomer. The measurements obtained suggest that the opening of the suture is triangular in nature with the base being towards the incisors and the apex in the nasal cavity.

Krebs (1959) used Vitallium implants in the infrazygomatic ridge of the zygomatic process and the alveolar ridge on each side lingual to the canines. He took frontal cephalometric radiographs after expansion, after stabilization, and after 8 months removable retention. His findings are illustrated in Fig. 4.6. He found that the increase in width of the dental arch during active treatment was about twice that of the basal maxillary segments, while the increase of the arch lingual to the canines was about half way between the other two. During stabilization, the dental arch was maintained by the appliance and even with the acrylic there was still a tendency for the alveolar ridge and basal segments to relapse during this period. He concludes that the rotation of the maxilla in the frontal plane is demonstrated by the greater increase in width between the alveolar implants than those in the zygomatic ridge.
Fig. 4.6 Effect of Expansion in various zones during different phases of treatment.  

(Krebs, 1959)

Wertz (1970) summarises his anteroposterior radiographs at the completion of expansion and again after 3 months stabilization. Wertz confirms the widening of the dental arch, opening of the midpalatal suture, and to a lesser extent widening of the nasal cavity. The lesser gain in the nasal cavity indicates an arc-like movement of the maxillary segments. Wertz felt that the resistance of the zygomatic arch to the forces applied inferiorly to this buttressing prevents parallel opening of the maxillary segments. This Wertz describes as being fortunate in that parallel opening would move the frontal process of the maxilla bodily into the orbital cavity. The pyramidal opening allows a greater gain at the occlusal level than at the palatal level which in turn is greater than at the nasal level.