MANDIBULAR ARCH WIDTH STABILITY WITH BEGG TREATMENT

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(SYDNEY)

A Thesis Submitted in Partial Requirement

for the Degree of

MASTER OF DENTAL SCIENCE

Department of Preventive Dentistry

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University of Sydney

1988

ABSTRACT

This study was undertaken to investigate mandibular intercanine and intermolar widths in orthodontic patients treated with the Begg appliance.

A sample of 35 patients was analysed, consisting of 7 first premolar extraction, 16 second premolar extraction, and 12 non-extraction cases. Intercanine width was measured at the cusp tip and buccal surface (facilitating axial representation of canine position), while intermolar width was measured from the mesiolingual cusp tip. Analyses of variance were performed on 2 sets of data, derived from slightly different subsets of the original sample. First, mean intercanine and intermolar widths at stages of treatment, i.e. pretreatment, end of treatment, and postretention were compared for each extraction group and cases with constricted, average, or expanded pretreatment intercanine width were identified within each group. Second, mean changes in arch widths during treatment and postretention periods were compared and these results related to the first set of analyses.

Mean intercanine width expansion and relapse for extraction and non-extraction groups was small, comparing favourably with results documented in related studies using the Edgewise appliance. Intermolar width measurements and changes substantiated interpretation of different patterns of intercanine width changes observed for each treatment. Comparison of the two sets of analyses revealed that pretreatment intercanine width as well as extraction group can affect canine movement during and after treatment.

ACKNOWLEDGEMENTS

The author would like to express his gratitude to the following people for their generous support in the preparation of this thesis:

Associate Professor Keith Godfrey, Department of Preventive Dentistry, for his supervision, subtle guidance and diligent review.

Dr John Dineen, for his invaluable scientific acumen and statistical assistance.

Dr Hilton Wasilewsky, Senior Tutor in Orthodontics, Department of Preventive Dentistry, for his advice and encouragement.

Mr Ken Tyler, Senior Technical Officer, Faculty of Dentistry, for his meticulous refinement of the measuring instrument used in this study.

Mrs Joan Thwaite, Librarian, Faculty of Dentistry, for her generous guidance in researching this topic.

Miss Bernadetha Sarono, for her help with the statistical analyses used in this thesis.

Miss Pip Mansfield and the orthodontic reception and nursing staff, United Dental Hospital of Sydney, for the hours spent reviewing records and recalling patients.

My colleagues and friends in the University Orthodontic Department who have contributed much toward a most rewarding course.

This thesis is dedicated to my dear wife, Kerry, and children, Steven and Laura, who waited patiently with endless tolerance and support over the duration of this orthodontic course and, in particular, throughout the preparation of this thesis.

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CHAPTER 1
INTRODUCTION

The success of orthodontic treatment is seldom judged in retrospect. That is, the patient may have experienced a gradual, even imperceptible transition from a condition, severe or otherwise, that is no longer relevant. Accordingly, success may be perceived, however unjustly, in terms of stability or relapse, however minor.

KAPLAN (1988) stated, "the problem of retention or its counterpart - relapse or treatment instability ... has not been satisfactorily answered by the multiplicity of authoritative statements and opinions, nor by clinical and experimental studies ...". While this statement casts a shadow of pessimism over orthodontic ideals and objectives, the orthodontist can manipulate the degree of stability governing treatment results, according to the limited variables recognized and potentially controllable. These factors include elective extraction, extraction site, appliance selection, and diagnostic criteria. The latter determine the priorities and compromise relating skeletal pattern and facial esthetics. This is a subjective assessment, and not readily identified in a retrospective study. However, the three former variables can be identified and evaluated in order to understand, rather than "answer" the problem of treatment stability. Thereafter, retention can be planned accordingly.

It is the purpose of this study to investigate non-extraction and extraction (two sites) treatments for a given appliance, the Begg appliance. Stability will be evaluated in terms of arch expansion, the parameters defining expansion being intercanine width and intermolar width. Specifically, the questions to addressed in this study are:-

1. Is dental arch width expansion or reduction evident during or following non-extraction, first premolar extraction or second premolar extraction treatments?
2. Is arch width stability enhanced or compromised by non-extraction, first premolar extraction or second premolar extraction treatments?
3. Is arch width expansion a reliable treatment objective as an alternative or in association with non-extraction, first premolar extraction, or second premolar extraction treatments?

ANGLE (1907) testified to the significant problems to be encountered in providing adequate retention. However, his primary diagnostic criterion was "normal occlusion", a highly controversial concept that stimulated an emotive debate regarding the principle of extraction in orthodontic therapy. Review of his philosophy and related arguments is therefore relevent to this study.

Although the determinants of alveolo-dental stability are not entirely understood, general factors have been implicated. Thus a discussion of the influence of the enveloping soft tissues, growth and development, and the periodontium is considered appropriate in understanding their relation to dental arch morphology, their susceptibility to mechanotherapy, and resultant postretention effects.

A review of clinical results related to the present study is presented with the respective findings summarised for comparison. It should be noted that these studies involved the Edgewise technique, with no corresponding literature available relating to the Begg technique. Relevant to this study, a summary of the Begg technique and treatment philosophy is also presented.

CHAPTER 2

EXPANSION AND EXTRACTION

—THE CONTROVERSY—

ANGLE (1907) stressed the importance of occlusion as the basis of the science of orthodontia. He emphasised occlusion as "the one grand object", and described its completeness including surrounding structures maintaining either "harmony or inharmony" in the development and arrangement of the teeth. He noted the three dimensional occlusal relations of the cusps and inclines, stating "The sizes, forms, interdigitating surfaces, and positions of the teeth in the arches are such as to give to one another, singly and collectively, the greatest possible support in all directions." He then stated, "... the cusps interlock and each inclined occlusal plane serves to prevent each tooth from sliding out of position, and further, to wedge it into position if slightly malposed." He marvelled, almost to obsession, at the design and function of normal occlusion; "... probably no other forms or relations could produce so beautiful and artistic an effect as an individual feature, or give so much of beauty in lines and expression to the face. The denture, with the teeth in normal occlusion, is a marked element of beauty to any face, however imperfect in other respects."

ANGLE emphasised the "most noticeable unbalancing effect of the mouth in its relation to the other features resulting from the loss of a premolar and retraction of the canine, or,

equally bad, the loss of a lateral incisor." He devoted an entire chapter to "Facial Art", again analysing balance and harmony, and stipulated a law "so plain and so simple that all can understand and apply it. It is that the best balance, the best harmony, the best proportions of the mouth in its relations to the other features require that there shall be the full complement of teeth, and that each tooth shall be made to occupy its normal position - normal occlusion." This doctrine was further emphasised in his criticism of earlier teachings where extractions were determined according to individual judgement, without any standard or law. He observed "It is gratifying to note, however, that this fallacious teaching and pernicious practice are rapidly passing and will doubtless soon become mere matters of history."

Just as ANGLE was the leader of the so-called "new school" of orthodontics, CALVIN S. CASE was the undoubted leader of the opponents of ANGLE'S tenets. CASE (1911) considered that the debate regarding extraction depended largely upon whether it is true or untrue that malocclusions of the teeth are due wholly to local causes, as proclaimed by the "new school", or whether they do not, partly at least, arise from the law of heredity and from other laws which govern the mixture of dis-similar types.

CASE saw a tendency among his contemporaries to attribute all the physical departures from the normal to degenerating or growth-perverting influences acting on the individual after birth, and this was seen as the only cause of malocclusion of the teeth. Also from the literature, he noted much "perverted and untruthful statements in regard to our teaching" and

accordingly reiterated his principles for extraction. Firstly, he maintained that whatever the malocclusion, the teeth can with few exceptions be placed in arch alignment and in normal occlusion. Therefore, so far as the relations of the teeth to each other are concerned, no dental malposition should be regarded as a basis for extraction. He then proposed that "no teeth should ever be extracted except in cases of excessive protrusions producing decided facial deformities ... and not even then, especially in young children, unless there is every indication of an inherent protrusion that will ultimately mar the beauty of the face for life." He also emphasised that "in nearly all locally caused malocclusions in immature arches, the final development of the jaws and general growth enlargement of the features demand all of the teeth and their sustaining alveolar arches to harmonize the facial relations." In total, he estimated that extractions were necessary in one in every twelve to fifteen cases. The fact that almost every orthodontist, after four or five years of experience, resorts to extraction in the correction of certain cases was considered prima facie evidence that this is the true principle of practice.

CASE was critical of ANGLE'S classification of malocclusion because it is based on the relation of the buccal teeth and gives no indication of the real position of the dentures in relation to facial outlines. Hence diagnosis and treatment are not indicated by ANGLE'S classification. CASE did, however, adopt this classification to illustrate his argument because it was the best understood and "the only rational classification for all who believe that in every case of irregularity the full complement of the teeth should be

preserved".

Although he didn't substantiate his claim, GRIEVE (1937) stated "we are now all pretty well in agreement that the horizontal growth of the jaws takes place occipitally, the developing molars playing a definite part in bringing about this enlargement." Like ANGLE, he believed that the dental apparatus supplies the chief stimulus to general growth and development of the jaws. Particularly when considering the modern diet it becomes quite evident how deficient is this "important factor". Thus in most individuals, there is not sufficient horizontal growth of the jaws to permit the eruption of the permanent molars without more or less forward displacement of the teeth in front of them, and to some extent the alveolar bone surrounding their roots. The whole dental arch is then forced into a position anterior to its normal relation to the apical base and to the cranium.

CRYER (1911) agreed with CASE in his belief that malocclusion at least partly arises from the law of heredity and from other laws which govern the development of plants and animals, and especially to laws which govern the mixture of dis-similar types. CRYER, in fact, took a firmer stand, stating "all irregularities and malpositions of teeth, barring those produced by accident, are the result of causes operating before conception. I fear that those who claim that all causes of irregularities of the teeth are post-natal have not read, much less studied the laws relating to heredity and breeding." He cited the writings of Mendel, Darwin, Weismann, De Vries, and Burbank.

DEWEY (1911), who had emerged from the "new school", was an enthusiastic advocate of ANGLE'S teachings and sharply refuted

the concepts of CASE and CRYER. He replied to CASE'S criticism of ANGLE'S classification by emphasising that it is based on "normal occlusion", this being the reason why it is universally adopted. He further rebuked CASE for not presenting any biological facts which would prove that malocclusions could be inherited or produced by the mixing of types and for suggesting that malocclusions which were the result of inheritance could not be treated without extraction. This criticism substantiated CASE'S earlier allegation of false representation of his teaching because in fact, he had stated that a very large proportion of "protrusions" (not malocclusions) which demand extraction for their correction arise from inherent causes (1912). DEWEY based his rebuttal, at least in part, of the role of inheritance in the etiology of malocclusion on the fact that syphilis and tuberculosis, once thought to be inherited, had since been proven to be otherwise.

DEWEY then adressed criticism of the concept of mechanical stimulation inducing bone growth by asking "if bone does not develop as the result of mechanical stimulation, how does it develop? In the study of the development of animals, from the single-cell animal with no skeleton or osseous structure, to the multicellular animal with complicated structure, we find evidence of mechanical stimulation throughout." The evidence, however, is not presented. He concluded, "every day arches are being developed as the result of mechanical force, mandibles are being induced to grow, and results are being accomplished that would be impossible without the growth of bone."

In a later essay on the "Evolution and Development of Normal

Occlusion", DEWEY (1931) concisely traces the inter-relationship of teeth, occlusion and function through prehension and deglutition from fish, reptiles and primitive mammals to modern man. He interpreted this account as further vindication of his previous convictions: "The evolution of occlusion has been the adaptation of organs to perform a definite function. Today, function is playing just as great a part in the production of normal occlusion as it did during the evolutionary changes that occurred years ago. Certain types of malocclusion occur because certain functional activities have become abnormal. In these cases, we find it impossible to maintain the proper relation of the teeth to the jaw and to the face and cranium, unless these functional activities can be established."

Other eminent Orthodontists were also involved in what became at times a bitter and personal exchange. HINMAN (1911) challenged DEWEY to explain how he would treat a bimaxillary protrusion, a challenge DEWEY evaded, except to insist that he would not extract. FERRIS and BOWMAN (1911) proclaimed their allegiance to the "new school" and the non-extraction movement gained considerable impetus over the "rational school" led by CASE. It wasn't until the 1930's after "a series of subsequent orthodontic relapses" that "extraction once again was being advocated as a proper treatment procedure in several types of orthodontic irregularities" (DEWELL, 1964). Principles and concepts were mostly derived from theorems or carefully selected cases rather than empirical evidence gained from scientific investigation. The controversy became known as "The Extraction Debate of 1911" and occurred at the time when modern orthodontics was passing through its infancy. It would

seem that today, some of the conjectures are equally ill-founded as the debate persists.

GRIEVE realised that malocclusion, as a general rule, was the result of a forward translation of the teeth. In some cases the forward displacement was so great, both in the maxilla and in the mandible, that it was impossible to carry the teeth back to their normal relation to the apical base and a "double protrusion" resulted. His diagnostic criterion here was ANGLE'S "line of harmony". To rectify this, a "radical procedure was resorted to." After many months of careful study and consultation with several of his "confreres", four first premolars were removed.

GRIEVE (1944) was to later further emphasise the "Forward Translation Theory" proposed by J. SIM WALLACE in 1904 and felt that this did much to clear up the problem of etiology in malocclusion. Thus, treatment based on this premise alone was to distalise the dentition. In reference to this treatment he concluded, "We earlier men in orthodontics worked earnestly to do what we thought was right, and in many instances we did what was wrong. We had a hard road to hoe." In opting for extraction treatment, he stated "The farther I have gone in carrying out this procedure in treatment, the more convinced I have become that it is wise in a large percentage of cases." He favoured four first premolar extractions because this left a lesser number of teeth to carry back.

LUNDSTROM (1925) considered that irregularities of the teeth were more than dento-functional problems as proposed by ANGLE. He considered that due to ANGLE'S great dominance and the protracted period necessary for treatment, it took a long time for the exaggerations of ANGLE'S theory to become fully

evident. He was also critical of CASE who opposed ANGLE'S normal occlusion dogma and "bone growing", but who also expanded retruded malocclusions anteriorly by the width of one premolar or more, and afterwards closed the spaces with artificial teeth.

In contrast to ANGLE'S theory on normal occlusion, LUNDSTROM stated, "In spite of the presence of an equipment of teeth normal both as to their forms and number, and independent of the occlusion and the original mutual relation of the jaws, the forms of the apical base can be or can become such that the position of the teeth becomes abnormal." He considered that anomalies in the development of the apical base are varied in their anatomical character and can appear at a very early stage, only to approach normal through a change in development occurring later on. They can alternatively remain unchanged or become progressive in character, again determining rather than reflecting occlusal function.

In the treatment of malocclusion with its various forms of deficiency in the apical base on the basis of attainment of normal occlusion, LUNDSTROM noted that there often remained an inclining position of the corrected teeth. This indicated insufficient space between the roots, that is an inadequate "apical curve". He comments further on ANGLE'S work, "It was pointed out long ago that for an orthodontic result to be considered definite it must be proved that the new position of the teeth was maintained after the removal of the retainer. It is a well-known fact that by the action of orthodontic treatment we can make teeth temporarily adopt entirely different positions from those which we are afterwards capable of maintaining." LUNDSTROM later refers to this as "exceeding

the orthodontic maximum".

HELLMAN (1940), midst the increasing weight of opinion to the contrary, stated, "The first and all-important aim in orthodontia ... was the establishment of normal occlusion of the teeth in dentitions with malocclusion." He believed that by putting the teeth in normal occlusion, "nature" is given a chance to be of help in the normal development of the other structures surrounding the teeth and he then presented selected cases to testify to this doctrine. In conclusion, reflecting on the trend away from ANGLE'S postulates, HELLMAN stated, "Unless our streamlined outlook and airconditioned aims of the present will change materially, orthodontic progress in the thirty years to come will definitely fail to measure up to that of the thirty years just past."

TWEED (1941) came to realise that he was unable to obtain the results demanded by DR. ANGLE'S teachings. That is, "too often after occlusion was gained something was lost in the balance, harmony, and beauty of the face." He reviewed the placement of teeth in the children of his practice and found that where beauty, harmony, symmetry, balance, and permanence of result had been achieved, the lower incisor teeth were on the ridge or basal bone. He adopted this criterion as a guide in diagnosis and treatment, instead of depending entirely upon the position of the cusps and upon occlusal relationships. He further commented that most orthodontists believe that if they establish a reasonably satisfactory cuspal relationship, regardless of axial inclination or the relation of teeth to their respective bony bases, occlusion will invariably direct the growth processes so that the maxillary and mandibular base bones will themselves grow forward and under the mesially

positioned teeth. They also believe that upon the completion of growth following orthodontic treatment, normal occlusion will be attained and the best in facial esthetics will result. This assumption is a "fallacy in an overwhelming percentage of our cases."

TWEED (1944) maintained that "normal occlusion or perfect facial esthetics can never be attained without the full complement of teeth." He conceded that "when a discrepancy between tooth pattern and basal bone does exist, it is far better to remove dental units to bring about a balance between tooth anatomy and basal bone." Failure to correctly position the mandibular incisors compromises the balance and harmony of facial esthetics, and compromises the permanancy of the end result. In reviewing his own results where bimaxillary protrusions were produced, he noted that "years of retention were futile, and, as a rule, collapse of the mandibular arch in the incisal region occurred as Nature endeavoured to correct this imbalance by positioning the denture back within the range of mechanical functional balance." Irreparable damage to hard and soft investing tissues in the incisal and first premolar areas was the usual aftermath. In cases where extractions were deemed necessary, TWEED agreed with GRIEVE in removing four first premolars.

STRANG (1943), like previous authors, acknowledged that the conscientious operator always aimed for the establishment of normal occlusion of the teeth. The one set rule of treatment was to produce the correct adjustment of occlusal inclined planes of all the teeth and to evolve dentures of good outline form with perfect tooth alignment. This was the "ideal and our orthodontic religion. We firmly believed that

stabilization would automaticallty be obtained if this standard of perfection could only be reached in our completed cases." (STRANG, 1946) Yet after the product of his efforts had been properly retained for a period of months and mechanical restraints had been removed, a large percentage of of relapses followed. From this he concluded, "the general conception of the normal and the interpretation of this conception in the form of treatment has not resulted in a stable product."(1943) He acclaimed TWEED for not only signifying this to the profession, but advancing a new theory supporting his philosophy and substantiating it with "most conclusive clinical evidence in the form of 200 consecutively treated cases in which results were stable."

STRANG considered that every malocclusion that we are called upon to correct represents a denture "under balanced force play." Hence the moment that we begin our treatment we are moving the teeth from locations of harmony with the stresses and strains that play upon them to positions of unequal pressures. Therefore these unequal forces must either be removed as part of the corrective procedure, or an inherent power of resistance placed on the various teeth which will enable them to oppose these "unconquerable etiologic factors dynamically."

He believed that the most vulnerable segments of the denture are the mandibular incisor and canine areas where 90% of recurrent malocclusion appears. If the positions of the first molar teeth are accepted as more or less a fixed anteroposterior point from which to establish an arch form, there are two ways to accommodate the denture units in perfect alignment; the buccal segments can be expanded laterally, or

the anterior segments can be advanced further anteriorly. He interpreted malalignment of the anterior teeth as "nature's method of compensating for the pressure" (from excessive muscle action or abnormal overbite) that the incisors are subjected to in causing the original malocclusion or during relapse after correction of the malocclusion. Given such pressures before treatment, combined with impairment of the growth pattern which "undoubtedly is the usual primary cause of malocclusions, and which is the reason that practically all malocclusions may be considered as complicated by forward positioning of the teeth in relation to their basal bone", STRANG questioned the rationale of further advancement of the dentition to gain alignment. TWEED recognised that if the incisors are the most frequent victims of the forces of displacement, they should be given the "greatest possible protection from this pressure and placed in such relationship to the basal bone that they would have good foundational support in occlusal stress." With this treatment priority, STRANG agreed with TWEED in discarding the first molars as key units in corrective procedures in order to retract the mandibular incisors to the extent necessary to relocate them on basal bone. STRANG further concluded that the prime motive that stimulated DR. ANGLE to continue his efforts to produce a more efficient appliance, "was the realization that teeth must be moved distally, in the majority of cases of malocclusion, if the normal was to be attained in treatment."

While the text of his earlier paper (1943) did not specifically address how the retraction of incisors to basal bone was to be facilitated, STRANG later observed that the ability to move teeth distally has been proven to be extremely

limited and the majority of operators who practised the TWEED philosophy of treatment in the early days of its introduction widened the dental arches to an excessive degree "in order to obtain alignment of the mandibular incisors and still keep them in a position of proper basal support, and coincidentally avoid the extraction of teeth." He then reported that "this error has now been recognized by TWEED and his followers and this accounts for the increased percentage of extractions now found necessary for ultimate stability in the end products of treatment" (STRANG, 1946).

Therefore, the two factors that STRANG considered essential to assure a stable result in treatment are "first, avoid changing the width of the deformed denture to any great degree, and second, do not move the incisor teeth forward in order to gain space for their alignment." He stated that the mandibular canine and molar teeth are key units in determining the limits of width in correcting the deformity and the buccolingual positions of these four teeth, in most cases, is controlled by the muscle force exerted on them. The muscles in action on the labial side are the canini, the triangulares, and the orbicularis oris for the canines, and the buccinators for the molar teeth balanced on the lingual side by the tongue. He concluded that the canines and buccal teeth must be moved backward to permit alignment of the incisors and "if this distal movement is to be other than of minimum amount, space must be provided for these tooth movements. The only way that this necessary denture area can be obtained is by the extraction of premolar teeth."

STRANG (1949) repeated his earlier assertions, acknowledging the conclusions of previous authors who determined that the

facial pattern is laid down very early in life and remains unaltered. Similarly, and of great importance in prognosis and treatment planning is the fact that growth centers, whose period of activity is completed, cannot be stimulated to renewed activity. He stated, almost in despair, that "clinical procedures continued along the same beaten path of denture expansion and mechanical retention, hoping against hope that primary mechanical and secondary functional stimulation would enlarge the supporting osseous bases beneath these expanded dentures so as to assure permanent results". Relapse occurred in "by far the largest percentage of treated dentures" and was conveniently attributed to "the great safety valve to conscience", pressure from malposed third molars. His conclusions again emphasised balance of muscular forces derived from tonus and contraction; the inviolate nature of intercanine and intermolar width; and the necessity for extractions when "it is impossible to rearrange the mandibular dental units in the desired alignment with the incisors re-established in locations overlying their basal supporting bone, without moving the canine teeth labially and the molar teeth buccally". He further concluded that if his treatment principles were adhered to, "it should be possible to eliminate mechanical retention at the end of active treatment and have a result that would remain stable."

HAHN (1944) also attributed relapse to the tendency to over-expansion of the buccal teeth and forward movement of the anterior teeth. He noted that early appliances produced a tipping of these teeth whereas later appliances with control over root as well as crown movement moved teeth bodily off their basal bones. Contrary to earlier theories, he stated

that no evidence had been produced to indicate that this would induce bone growth or lateral growth of the body of the maxilla or mandible and he considered this belief to be no longer tenable.

McCAULEY (1944) considered that the first signs of collapse occur in the region of the lower cuspids and that through treatment great care must be taken to protect this region. His treatment philosophy was perhaps summarised in his statement, "Since these two mandibular dimensions, molar width and cuspid width, are of such an uncompromising nature, why not establish them as fixed quantities and build your arches around them?" Distinguishing their relative significance, he stated, "The orthodontic bible has been built around the inviolability of the key tooth, the six-year molar." His interpretation was that the first molar is the principal key to the development of the arches in the early years, but the cuspids come to play an equally important role in the permanent dentition.

NANCE (1947) analysed each of the available methods that may be used to align teeth in nonrotated positions. He specifically mentioned that growth, per se, is not considered because "while growth can and does enlarge the area in which teeth nay be placed, it performs this function in limited regions and not just wherever we might wish it." He believed that distalisation of buccal segments, besides being difficult, will relapse forward again. Labial movement of mandibular incisors "is suicidal" except in Class II division 2 malocclusions and Class I cases which resemble them, where the mandibular incisors have an abnormal lingual axial inclination maintained by a deep overbite or some other

mechanical means, that is, lip pressure or finger pressure. Similarly, he dismissed buccal expansion as a reliable procedure, except where "there is contraction of the dental arches in the molar and premolar regions which can be corrected by careful widening." While overexpansion of the buccal segments does not greatly affect the appearance of the face in repose, the "orthodontic mouth" is revealed in all its doubtful "glory" when the patient smiles.

These conclusions and the effect of rotations of teeth on arch length were determined after a long-term study of information revealed by what he called "outside" (arch perimeter) and "inside" (arch length) measurements. Expansion failed in the majority of cases as a satisfactory solution to the problem of arch length, since the greatest permanent increase in the outside measurement attained was only 2.6 mm. He stressed that this "is not an amount one may expect routinely to gain and maintain, but, ... a maximal figure." The only cases where buccal expansion may be utilised are those in which basal supporting bone has adequate width and the contraction is confined to the alveolar bone. Even in malocclusions where buccal expansion is most clearly indicated, the results were "pitifully inadequate". His measurements "clearly show the limitations of expansion, and also show that unduly prolonged retention has no bearing on ultimate success or failure." NANCE concluded, "If the full complement of teeth is to be preserved, the only means by which the labial-axial inclinations of anterior teeth can be corrected is through what little increase in room can be gained through buccal expansion."

The inside measurement was permanently increased "only in

those infrequently encountered cases where actual mesial tipping of mandibular first permanent molars had occurred as result of premature loss or congenital absence of mandibular second premolars; or where there was lingual tipping of mandibular incisors requiring that they be uprighted. In all other types of cases, the increase in the inside measurement, obtained through the distal movement of posterior teeth of the labial movement of incisors, was either transitory or gained at the expense of facial balance." It was also found that the distal movement of mandibular molars and premolars "will not lead to a permanent result, regardless of the presence or absence of mandibular third molars."

Having presented abundant evidence exemplifying the limitations of non-extraction orthodontics, NANCE stated, "it is not possible for me, and I believe it is possible for no one, to show results in difficult, crowded cases which have held satisfactorily when extraction was not a part of the treatment." He considered the removal of the four first premolars a step in the right direction but cautioned against closing extraction spaces entirely by distal movement of the canines and lingual tipping of the incisors following the extraction of four first premolars. The resultant "dished in" faces can be avoided by unravelling the rotated anterior teeth into the spaces, or tipping the incisors lingually to, but not beyond, their normal axial positions followed by closure of any remaining spaces by bodily mesial movement of the posterior teeth. NANCE later indicated that "the routine designation of these particular teeth for removal is not justified."

HOWES (1947) recognised the contribution made by ANGLE in

stating, "ANGLE'S teachings very effectively turned the trend of orthodontics away from treatment by extraction, which shift was most beneficial to the profession, as it encouraged the members of the profession to more exacting efforts and also enabled them to see what could be done without extraction." He referred to that period of orthodontics as "twenty odd years of experimentation on the part of ANGLE and his followers in trying to maintain a full complement of teeth in every or practically every case treated". He then acknowledged the work of LUNDSTROM, who "pointed out quite clearly that there were some dental irregularities which could not be permanently corrected when treated according ot the teachings of ANGLE", and TWEED who "contradicted the teachings of his teacher ... to bring the subject more emphatically to the attention of the profession." He quoted from LUNDSTROM, "Instead of regarding from a therapeutic point of view the anomalies of the positions of the teeth as simply or principally occlusional problems, henceforth ... regard them as being in equal degree problems of the apical base, and the object of treatment will be the attainment of an occlusion possessing a functional and hygienic optimum." HOWES agreed in concluding "in a considerable number of cases, this optimum cannot be normal occlusion."

HOWES investigated the apical base by surveying casts and by taking direct intra-oral measurements. His observations added to the weight of evidence appearing in the literature concluding that a normal occlusion must be supported by a normal apical base and large percentage of malocclusions have a deficient or deformed apical base. He also found that when the apical base in the premolar region is of insufficient

width, the premolars and anteriors will either be crowded or forward of their normal positions. Again, this was consistent with the observations of GRIEVE, TWEED and STRANG. Finally, he found no evidence to suggest that mechanical orthodontic therapy can directly affect the size of the apical base. However, he postulated that "by making possible normal muscular action in breathing, chewing, swallowing, facial expression, etc ... it seems plausible that the apical base could be given an opportunity of achieving more normal dimensions".

HOWES (1960) later referred to direct expansion (lateral enlargement of the dental arches by orthodontic forces) and indirect expansion (where the premolars and cuspids assume a postion in a wider part of the arch). He noted the trend reversal where "arch form cannot be changed ... extraction is obligatory in a very high percentage of cases if treatment objectives are to be obtained." Reflecting on the rigidly opposite views previously reported, he "wondered whether lateral enlargement of the coronal arches had been given a really fair trial - not as a panacea, as it was used originally, but in selected cases ..." This was qualified by stating, "Teeth should never be tipped buccally or labially beyond the limits of their normal relationship with supporting bone" or as he later described it, "outside the limits of the basal arches".

He believed that relapse of expansion was magnified because expansion was generally done "after the permanent side teeth had erupted". That is, if the alveolar process is formed it is therefore not as susceptible to possible molding as it is when treatment is started in the mixed dentition and carried

through the period of eruption of the permanent buccal teeth. In the permanent dentition basal arch width from the first premolars forward cannot be increased. In cases in which intercondylar width increases considerably, HOWES believed that basal arch width does increase below the molars and possibly below the second premolars. In this case, the molars can be expanded and if arch length is fully maintained, some space for the crowded incisors can be obtained by moving the canines distally. He also believed that when the mandibular first premolars are extracted, the intercanine distance can be increased by moving the canines back into a wider part of the arch.

He concluded that almost all mixed dentition cases are "not foreshortened arches, as one is led to believe through the current misuse of the term arch length". They were considered to be "narrow coronal arches" which could be expanded if a favourable facial pattern is evident (Frankfort-mandibular plane angle less than 28 degrees). Good basal arch, bizygomatic and bigonial width and good arch length were also considered favourable.

BJORK (1951) considered that bimaxillary protrusion accompanied by a marked forward inclination of the incisors is in many cases a normal occurrence in Europeans, and "does not in itself imply any need for orthodontic treatment unless it is accompanied by irregularities in the tooth position or in the occlusion." He found that during the growth period the alveolar prognathism diminishes, the profile becomes straighter, and the incisors become more upright. Crowding is a "distinct symptom of a general reduction in facial prognathism, due to a shortening of the jaws, and hence not

merely a shortening of the alveolar arches."

In certain cases of crowding BJORK believed that tooth extraction is "warranted as a necessary measure in the orthodontic treatment in order to prevent overexpansion ... in accordance with TWEED'S method of treatment." However, BJORK differed from TWEED in not stipulating a general aim in orthodontic treatment to correct the incisors to a practically vertical position. He believed instead that the position of the incisors accommodates itself to the jaw structure, that is, overjet is in many cases partly compensated by the inclination of the incisors when the difference in maxillary and mandibular prognathism is great. Thus the mandibular incisors are often found to have marked forward inclination in cases of pronounced maxillary overjet. Correction of the incisors to an upright position in such cases would serve to accentuate the overjet. Treatment in such cases should aim at correcting the incisors according to the jaw structure. TWEED (1954) did, however, make a similar observation, and accordingly used the phrase "compensating the inclination of the mandibular incisors for varying FM angles".

BEGG (1954) stated that occlusion is not a static condition. "The relationships of individual teeth in the same arch, the relationships of the teeth of one arch to those of the opposite arch, and the positional relationships of the teeth to the jawbones change continually throughout life. Therefore, the only constant in correct occlusion is continual change." Consistent with this philosophy, physiological movement occurs throughout life and determines the position of the teeth in the jaws through continual migration in two directions: horizontal (mesial migration) and vertical

(continual eruption). Previous authors considered that mesial migration of teeth is an aberration, with no satisfactory physiologic or biomechanical explaination, and producing malocclusion. However, BEGG believed "On the contrary, it is undoubtedly quite a normal and vitally necessary physiologic process related to, and part of, the process of continual tooth eruption." The other important factor he considered was the changing anatomy of teeth where attrition occurs interproximally and occlusally. This was considered a "normal functional process and absence of this loss produces abnormalities." Textbook normal occlusion persisting in adults was seen as "an astigmatic image, a distortion" and exists because the modern diet is too soft and concentrated to cause tooth attrition. BEGG further determined that high, unworn cusps prevent the jaws from assuming correct relations to each other in all directions, but especially in the vertical direction because they are kept too far apart.

Given these normal physiological conditions, BEGG illustrated his concept of normal occlusion with Aboriginal Australian dentitions which demonstrated dental morphology not seen among civilized groups, namely "anatomically correct or attritional occlusion." This is diametrically at variance with the concept of normal oclusion proposed by ANGLE. In fact, based on BEGG'S theory, the textbook normal occlusion of ANGLE would not exist in Primitive Man as the cusps and inclines would wear as the teeth became functional. Therefore ANGLE'S normal occlusion could not be the underlying functional stimulus encouraging and directing growth of the jaws and no evolutionary advantage or significance pertaining to jaw growth could be attributed to it.

Due to early attritional reduction of the mesiodistal lengths of the permanent molars in Stone Age Man, undesirable overlapping rotation and bimaxillary protrusion of the six anterior permanent upper and lower teeth which would bave been inevitable in the absence of attrition is avoided. Unimpeded eruption of the third permanent molars is fascilitated. BEGG concludes, "On the other hand, absence of tooth attrition in Civilized Man, in those cases which have a similar degree of preponderance of tooth substance over bone substance that would develop anatomically correct occlusion in Stone Age Man, produces malocclusion because the delicate balance between tooth size and bone is not maintained throughout the developmental period of tooth eruption of the dentition."

BEGG considered the comparison of the occlusion of the teeth of Stone Age Man with that of Civilized Man presented "sufficient evidence that orthodontic extraction of teeth of the second set is not empirical expediency, but a rational procedure with a sound etiological basis, as it simulates the extensive mesio-distal attritional reduction of tooth substance in Stone Age Man." In cases of mild tooth crowding, he stated that "slight orthodontic arch expansion without tooth extraction may produce stable results." In most cases of crowding, with no more excess of tooth substance than would be eliminated by attrition in Stone Age Man, he found no difficulty in deciding that the four first premolars should be extracted. In cases where such a preponderance of tooth substance exists that pronounced tooth crowding, overlapping, and double protrusion would develop even if there were extensive tooth attrition, eight teeth are extracted. When these extreme cases presented at an early age, the four

permanent first molars were extracted immediately and the four first premolars were extracted prior to fixed appliances at a later stage.

However, DAWES (1986) considered during his study of the occlusion of Prehistoric Man and indigenous racial groups of North America and Australia, that the traditional understanding of interproximal attrition needed revision. He believed that the extent of interstitial wear in the occlusion of the immature Australian Aborigine has been overestimated by BEGG (1977) and that until further study is undertaken, Murphy's interproximal attrition rate of 0.3 mm per annum for mature arches should be used as the basis for the assessment of immature arches. According to DAWES, this meant that in the adolescent Australian Aborigine, interproximal attrition would have been expected to contribute only 1.0 mm of space per side towards the provision of adequate space for third molar eruption. He therefore concluded, "The suggestion that the lack of interproximal attrition in Modern Man is a cause of canine/premolar or incisal crowding, is without foundation." Contrary to BEGG'S earlier rationale for extraction, based on his assessment of attritional reduction of total arch length of half an inch or more by third molar eruption, DAWES stated, "irrespective of what other causes there may be to warrant the extraction of teeth in a treatment plan to correct crowding in the Modern Child, the lack of interproximal attrition is not a factor."

RIEDEL (1960) evaluated several laws derived from the literature, relating to retention. One of those discussed stated, "Arch form, particularly in the mandibular arch, cannot be permanently altered by appliance therapy, therefore,

treatment should be aimed at maintaining, in most instances, the arch form presented by the original malocclusion." He noted that evidence presented by NANCE, McCAULEY, and STRANG "lent credence to this type of thinking".

RIEDEL examined two separate samples of completed cases. From the first sample of "about a dozen cases" out of retention five years or longer, he found that "in no instance was there any exception to the rule that mandibular canine width returned to its original dimension." From the second sample of eight nonextraction and five extraction cases treated by TWEED, he noted "exceptions to the rule of inviolability of mandibular arch form and intercanine width, but we cannot expect all of our patients to be exceptions". In conclusion, he classified retention according to the requirements of various types of cases, and determined that permanent or semi-permanent retention is necessary where expansion has been carried out in one or both arches.

As BALLARD (1944) indicated, the early perception of man's dental apparatus was that of a "potentially perfect machine, harmonious in all its parts, needing only a skilful rearrangement by the orthodontist to render it functionally and esthetically perfect." He then typified an increasing wave of rebellion in stating, "This point of view is sound in its larger aspects, since the fact is demonstrated by every orthodontic case which is carried successfully to the end of active treatment, but when analyzed in minute detail it is manifestly deficient." BROADBENT (1941) expressed a similar sentiment based on his assessment of accumulated serial records of more than 1,000 orthodontically treated cases. Comparing the progress of developmental growth in this series

with the serial records of the Bolton Study of over 3,000 non-treated individuals, he stated, "it is convincing that, granting the correction of the malarticulation of the teeth which is accompanied by some change in the alveolar process, there is little actual alteration in the bony contours."

It is evident that as the extraction debate continued through the evolution of orthodontic diagnosis and treatment, most authors and the bulk of clinical evidence regained respectability and lent credibility to the practice of extraction. The question of stability then focussed on the indications rather than the concept of extraction. This was typified by LINDQUIST (1958) who introduced his essay by stating "It is not the purpose of this article to discuss the extraction and nonextraction issue, for it is obvious that, in order to follow the various formulas proposed for positioning the lower incisors, teeth will have to be extracted in a significant percentage of cases."

PROFFIT (1978) summarised the view currently presented in established orthodontic teaching, combining concepts central to the "Equilibrium Theory". He stated, "It is well-known now that extraction of teeth is required in some cases, but the percentage of extraction cases varies greatly among orthodontists. That percentage reflects more than anything else a judgment as to the importance of modifiability of the equilibrium of environmental forces around the dentition."

Thus the debate was refined to differentiate the cases requiring extraction from those that could be resolved by arch expansion. More specifically, much empirical data has since been documented to assess incisor proclination and buccal expansion.

CHAPTER 3

DENTO-ALVEOLAR MORPHOLOGY AND MUSCLE BALANCE

3.1.GENERAL CONCEPTS

WEINSTEIN et al (1963) believed that "an understanding of the effects of the enveloping musculature upon the conformation of the dental arches into which the individual elements of the dentition fit" is essential to both clinical orthodontics and the study of growth and development of the dentition. They described the "equilibrium theory of tooth position" where an "element of the dentition" in a state of equilibrium will not be moved by the natural environmental forces acting upon it. These forces may be exerted by "adjacent musculature, adjacent elements of the dentition, occluding elements of the dentition, other interposed materials, i.e. food bolus, thumb, fingers, etc., and of particular importance, the forces exerted on the root of the dental element by the surrounding bone acting through the periodontal ligament." Conversely, according to this hypothesis, "if a time-linked resultant force were to exist in the periodontal ligament, the tooth would be expected to move to a position relieving this condition."

Orthodontic treatment can alter the influence of each of the contributory factors which determine tooth stability by changing occlusal relationships and arch-form, and due to the extraction of dental units which maintain the integrity of the

alveolus. RIEDEL (1960) noted that muscular pressure (among other factors) should be considered in determining the type and length of retention. He further stated that retention is dependent on the occlusion established, which "must be within the bounds of normal muscle balance and that occlusion and muscle balance established are dependent upon the amount of apical base available and the relationship of apical bases to one another."

RIEDEL, and later, SHAPIRO (1974), attributed the concept of "establishing proper muscle balance" to ROGERS (1922) who advocated muscle exercise as an aid in facial development. ROGERS observed the effects of muscles "tearing down the results of years of our mechanical efforts", but believed that muscular forces could be considered as corrective agents, and utilized in prevention, treatment, and retention. He suggested that muscle training be given "greater consideration ... at least, for a short period to the exclusion of the invention of any further mechanical orthodontic apparatus." From a conceptual and environmentalist standpoint, he instigated the muscle balance controversy as ANGLE did the extraction debate.

3.2.EARLY ASSERTIONS

GWYNNE-EVANS (1951) studied the development and maturation of swallowing. He noted its clinical application in orthodontics with regard to frequency (deliberate and subconscious, day and night), and the observations of Rix and Ballard relating the muscular environment to dento-alveolar

alignment. He stated that "in considering the aetiology of dental mal-occlusion, it is just as necessary to relate dental alignment to the behaviour patterns of the oro-facial muscles within whose influence the teeth erupt, as to relate dental alignment to the size, form and relationship of the jaws on which the teeth are based."

STRANG (1952) analyzed before and after models of cases he treated that had remained stable, and those that relapsed. He found that the stable cases maintained an intercanine width consistent with the original, and the unstable cases collapsed to the original dimension. From this he proclaimed the following axiom: "The width, as measured across from one canine to the other in the mandibular denture, is an accurate index to the muscular balance inherent to the individual and dictates the limit of denture expansion in this area in treatment". He adhered to this axiom of non-expansion, except where canines were moved distally into the spaces created by the extraction of the first premolars. STRANG (1954), in detailing case analysis, indicated the necessity to "note the effect of muscular pressure upon the denture form." He stated emphatically, "a denture in malocclusion is a denture in balance, and treatment planning must take this into consideration. If this inherent muscular balance is violated in corrective procedures, the stability of the final result is proportionately jeopardized."

BRODIE (1953) described the tongue's backward and forward motion in contact and within the confines of the buccinator muscle as "an admirable pump plunger or sucking device". He considered that "the eruption of the teeth and the growth of the alveolar process separates the two, but the position and

form of the dental arches are determined by the line of equilibrium set up between tongue and buccinator."

RIX (1953) focussed on the significance of muscle function exerting its influence during mastication and swallowing. He considered mastication to be a "balanced play of activity between the lips and cheeks on the outside of the arches and of the tongue lying within" which guide food and serve to maintain the "radial positions of upper and lower teeth closely related." The intermittently exerted muscular stress of swallowing "adds its contribution to the moulding forces created by mastication."

TULLEY (1953) illustrated with a "cine-film" the muscle activity associated with each of the Angle's classes of malocclusions. Particular reference was made to swallowing patterns and their varied potential for modification during orthodontic treatment in order to obtain "a position of balance between the labial and lingual forces" and implied stability. TULLEY (1962) later stated, "So many of the activities which were labelled `atypical behaviour of the soft tissues' have been shown to be primarily adaptive modifications, reflexly etablished, because of abnormal morphology, either due to abnormal dental base relationship, or to the shape and size of the soft tissues, or both." In 1969 he classified tongue-thrusting and determined that "only a very small percentage of orthodontic problems are ultimately complicated by it." He considered that there had been "an overconcentration on the effect of the soft tissues on malocclusion" and concluded that "it is better to place the emphasis on the morphology of the skeletal and soft-tissue structures which demand abnormal posture and activity, rather

than on the more transient and rapid movements of the tongue in speech and deglutition."

HOVELL (1956) believed that "the dento-alveolar structures should be regarded, like the muscular processes of bone, as being entirely moulded by soft tissue action and morphology." He substantiated this view citing Negro dento-alveloar prognathism which he maintained was the result of the soft tissue morphology, i.e. full lips and a forwardly placed tongue, and could not be retracted to a stable position by orthodontic treatment. Similarly, prosthodontists set full dentures "in a position of balance between lips, cheek and tongue in the certain knowledge that if they were not, they would be unstable". He attributed the majority of Class II cases to variations of soft tissue morphology, stating that "the skeletal morphology of Class II cases has been shown to fall, for the most part, within the normal range of variations in Class I occlusions." Thus, the soft tissue morphology was considered to have a primary influence on the shape, size and position of the dental arches, with variations in behaviour (e.g. swallowing action) all important in the production of maolcclusion. He believed that there was no evidence that the shape or size of the dental arches is affected by tonsils, adenoids and mouth-breathing. Digit sucking was also discounted as a primary determinant of malocclusion, but rather is "associated with an atypical swallowing action, and it would seem likely that a common genetic factor is responsible for the production of the sucking behaviour pattern and the oro-facial behaviour pattern."

HOVELL (1955) considered the effect of normal soft tissue patterning to be passive, with the lips and cheeks exerting "a

constant slight pressure against the solid muscular mass of the tongue." He concluded, "The size and position in the mouth of the tongue, therefore, is the primary determining factor in the shape and position of the dental arches in the absence of any abnormal muscular behaviour pattern." Three distinct atypical swallowing patterns were described, each producing a different effect upon the dento-alveolar relationships and influenced in the effect it produces by the function and posture of the lips and by the skeletal pattern.

BALLARD (1957) believed that malocclusion was the result of inherited variations, not the result of environmental factors acting postnatally. This premise was later reiterated (BALLARD, 1962), adding, "clinical work has demonstrated very clearly that individuals have characteristic postures and patterns of movement which are peculiar to themselves and over which orthodontists and speech therapists have no control." Accordingly, he refuted the earlier concepts of ROGERS regarding muscle exercises and the correction of mouth-breathing and skeletal discrepencies. Based on his "physiological and biological approach", BALLARD stated, "it is possible to analyse soft-tissue and skeletal features and plan treatment in such a way that the teeth are put into a stable position, such a position being maintained by posture and behaviour which are within the physiological capabilities of each individual."

BALLARD (1963) stated "It is generally accepted that the dento-alveolar structures are in linguo-facial balance in the environment of the soft tissues." However, his interpretation of functional regulation varied from that of HOVELL. He postulated that "the two primary factors in the positioning of

the labial segments are lip form, posture and behaviour and the skeletal pattern. Only secondarily does the tongue, by its adaptive behaviour, mould the labial segments against the lips. Its adaptive behaviour is produced quite instinctively by sensory feedback." The limited potential of orthodontic correction for a given lip morphology was considered to be evident where bimaxillary proclination resulting from full everted lips can be reduced "only a limited amount, equivalent to about 5 degrees change of axial inclination. A greater reduction results in a relapse with spacing."

GRABER (1958) stated, "It is the constant postural muscle relationship, as modified by malocclusions or by those active but less frequent functions of mastication, deglutition, respiration, and speech, that has the most profound and lasting effect on the facial and dental morphology - all within the guiding frame of the hereditary pattern and the growth and developmental processes." While this statement leaves nothing to chance regarding the etiology of malocclusion or tooth position, he did indicate that "electromyographic studies have shown, even at physiologic rest, muscle is in active function, maintaining a status quo of soft-tissue and skeletal elements." He concluded, "It is this postural position, or changes in the resting positions of the draping musculature, then, that is the more likely basis for the resulting bone morphology".

As SCOTT (1961) surmised, the thesis that "normal dental arch form is determined by the forces exerted upon the teeth by the musculature of the tongue, lips, and cheeks" had become ortthodox teaching and "more or less universally accepted". GWYNNE-EVANS (1956) noted that the hypothesis that "the teeth

are aligned within a state of balance between the muscle forces surrounding them" was unproven. However, he considered it justified according to the quotation: "A hypothesis is not a conclusion; it is a starting point for observations and it should not be repudiated for want of scientific proof". SCOTT believed it had become dogma and, although based on many years of clinical experience, highly vulnerable. He queried the following aspects: "(1) How labile is alveolar bone? (2) What pressures are exerted by the musculature of the tongue, lips,and cheeks? (3) Are these pressures of an intensity, duration, and nature which would render them capable of acting in the manner postulated?"

3.3.EQUILIBRIUM THEORY REVISED

The pragmatic environmentalist interpretation of muscle function proposed by ROGERS, to the equally rigid adherence to the principles of genetic determination theorized by BALLARD, encompassed a spectrum of dento-alveolar etiology, which initially varied in degrees by convenience and evolved to implicate posture and morphology by necessity.

GWYNNE-EVANS' explanation of arch morphology focussed on behavioural patterns, particularly swallowing, with an emphasis on genetic determination in his discussion on inherited patterns. STRANG and BRODIE propounded the simplistic concept of muscle balance between tongue and buccinator, pre-empting the elaborate statement by WEINSTEIN et al. RIX developed this concept with particular bias toward muscle function, specifically mastication with intermittant

input from swallowing. TULLEY'S perceptions initially concerned muscle function (swallowing), were later qualified to stipulate a more adaptive role of functional activities, and finally evolved to emphasise skeletal and soft tissue morphology, critical of earlier emphasis on rapid functional movements. HOVELL attributed arch morphology to soft tissue function and morphology with a degree of genetic determination regarding associated habits and oro-facial behaviour patterns. He also alluded to resting (postural) pressures of the lips against the tongue. BALLARD considered variations of occlusion to be inherent, this determination mediated by posture and function. GRABER similarly described a multifactorial etiology with hereditary bias, based primarily on postural/resting pressures and modified by functional aberrations.

WINDERS (1958, 1962) presented a comprehensive assessment of lingual and buccal/labial resting pressures which was often cited in subsequent studies, revealing a general consistency in values recorded by other authors. WERNER (1964) recorded resting pressures slightly higher than other studies, and found them to be dependent on head posture. Significantly, WINDERS found that mandibular lingual resting pressure was greater than buccal resting pressure in the molar region, whereas in the incisor region, higher pressure was recorded from the labial musculature. LUFFINGHAM (1969), and GOULD and PICTON (1968) reported statistically significant differences of buccal/labial pressure between groups according to overjet and Angle's classification respectively. However, these variations were small and not consistent, and therefore the clinical significance is questionable. Additionally, much

variation was apparent within the groups. Contrary to other studies, PROFFIT et al (1964) and LUFFINGHAM found little or no evidence of resting pressure from the labial musculature in the upper anterior region.

Forces generated during function consistently demonstrated lack of balance between the tongue and perioral musculature. Evidence supporting this contention, although at times contradictory, compounded the complexities of dental stability. WINDERS found no evidence of labial contraction associated with normal occlusion during swallowing and only slight increase in labial pressure associated with openbite cases. Contrary to these findings, KYDD et al (1963) demonstrated increase in labial pressure with normal occlusion and less pressure than normal occlusion associated with open-bite cases. PROFFIT et al, GOULD and PICTON, LUFFINGHAM, and WERNER all concurred with KYDD et al in demonstrating labial pressure to be associated with normal swallowing. GOULD and PICTON, WERNER, and LUFFINGHAM showed that the greatest increase in labial pressure was to be found in cases with increased overjet. WINDERS and PROFFIT et al demonstrated an increase in lingual pressures during swallowing, KYDD et al showed that anterior open-bite cases produce twice the lingual pressures of normal occlusions, and KYDD and NEFF determined that, since tongue thrusters swallow at a slower rate than normal occlusions, the same muscle force is expended in both cases. The inverse relationship established by PROFFIT et al between lingual pressure and arch width, and the estimates of 24-hour muscle function by LEAR and MOORREES (1969) further discredited the assumption that dental arch form directly reflects the influence of the

surrounding buccolingual musculature.

SCOTT (1961) presented the following summary of dento-alveolar development:-

1. Individual bones have an inherent shape which shows itself early in foetal life before any muscle forces are active.
2. The primary form of the alveolar processes and dental arches is determined before birth prior to the eruption of the teeth and independent of muscle activity.
3. The postnatal development of the alveolar processes and dental arches is such that arch form is maintained in spite of the greater pressure exerted by the tongue as compared with the lips and cheeks.
4. The wide variation in the form of the arches ... is unlikely to be explained in terms of tongue shape or the balance between the tongue and lip musculature.

He noted that various etiological associations between muscle function, postural position, and arch morphology have been elevated from "accurate clinical observation ... into a dogma". He considered that swallowing is unlikely to produce deformity: "If the tongue does exert a pressure capable of producing open bite or protrusion of the upper incisors, it is almost certainly because the pressure exerted is more continuous and greater than in normal swallowing and is the result of a tongue thrusting babit." SCOTT presented the following summary concerning functional influence in the etiology of malocclusion:-

1. Abnormal muscle action produces bone deformity.
2. Certain forms of malocclusion, involving the anterior teeth, are closely associated with certain postural and

behaviour patterns of the musculature of the tongue and lips.

3. These factors may themselves be considered as the causes of the associated dento-alveolar abnormalities, or as contributing to and exacerbating the skeletal abnormality, or if they are acquired habits and not inherent factors, being themselves the result of the skeletal abnormality.

PROFFIT et al (1969) considered that the arch distortion which accompanies micro- or macroglossia and oral habits is indicative of tongue function playing some role in the development of the dental arches. They measured maxillary lingual pressures in children and found that for those with normal skeletal jaw relationships, "lateral pressure decreased as arch width increased, and this negative correlation approached statistical significance." It was suggested that "factors which control arch width appear to operate rather independently of lingual pressure". Effects due to tongue function can be observed, but "only outside the range of normal variation", e.g. tongue malformation.

The inverse relationship between arch width and lateral tongue pressures reported by PROFFIT in 1969 was consistent with his later study comparing the functional pressures during swallowing of Australian aborigines, with those of Americans of northern European descent (PROFFIT et al, 1975). They found that although tongue activity during swallowing in the two groups is similar qualitatively, "the inverse relationship between tongue pressure and arch size really becomes obvious when the Australian aborigines, with their generally large arches and low tongue pressures, are compared to Americans,

who have higher tongue pressures and smaller dental arches." Lip pressure during swallowing was found to be slightly smaller in Australian aborigines, and no quantitative difference was found during speech. Consistent with previous studies, there was no labio-lingual balance during function or rest. They concluded, "Resting lip pressures are relatively constant in Australian aborigines and Americans despite the difference in arch dimensions. This suggests that expansion of the arches ultimately may be limited by lip position and tonicity, and therefore that these are the important environmental determinants of tooth position."

PROFFIT (1978) considered the four primary factors in eequilibrium to be:-

1. Intrinsic forces by tongue and lips.
2. Extrinsic forces: habits, orthodontic appliances.
3. Forces from dental occlusion.
4. Forces from the periodontal membrane.

He noted that equilibrium of the lingual and perioral musculature has not been demonstrated at rest, during function, or combined and related to duration. Extrinsic forces were considered to be "effective when their duration approaches fifty percent of the time, and some impact can be produced by durations of only a few hours." He believed that the dental apparatus is "an effective hydrodynamic damping system ... well-adapted to resist short-acting forces such as those generated during chewing, speaking and swallowing where the duration of force application is typically one second or less." Therefore, tongue thrust is more likely to be effect than cause. However, "resting pressures of tongue and lips have durations which are entirely consistent with importance

in equilibrium". He further suggested that forces from within the periodontal membrane (produced by metabolic activity) could stabilise the teeth after their final vertical positions have been attained, i.e. "maintain teeth in stable positions despite an imbalance between resting tongue and lip pressures." He implicated as evidence "the migration of teeth which often is observed as periodontal breakdown occurs" and studies demonstrating eruption force between two and ten grams.

PROFFIT nominated secondary factors that may influence arch morphology. Low mandibular and tongue posture associated with a forward position of the head, "could lead to constriction of the maxillary dental arch ... and perhaps to anterior open bite". These conditions may manifest as physiological adaptations which facilitate mouth breathing associated with respiratory obstruction.

The contribution and controversy of the "Equilibrium Theory" has stimulated much investigation into factors determining arch morphology, and accordingly, tooth stability. It has been demonstrated that muscle balance does not exist; at least not as defined by present parameters. Intermittent functional activity is now generally discredited as a primary etiological factor in arch morphology and consequently, relapse. Resting posture and eruptive/periodontal forces have been strongly implicated in this regard and WEINSTEIN'S (1967) discussion on minimal forces in tooth movement suggests this is feasible. Skeletal posture may indirectly be a determining factor. ABRAMS (1963) qualified the general assertion that "the denture is controlled by the opposing muscle forces ... any attempt to alter the shape of the dental arches by artificial

means is bound to fail". He stated, "since the point of balance is a function of growth, an alteration of the denture form at the onset of treatment may well place the teeth in a position of balance at the end of treatment, eighteen months later."

CHAPTER 4

GROWTH AND DEVELOPMENT

4.1.MANDIBULAR DENTAL ARCH GROWTH AND DEVELOPMENT

4.1.1.Introduction

BARROW and WHITE (1952) highlighted the significance of a detailed understanding of growth, stating "Since most orthodontic patients are growing children, knowledge of growth becomes important in the ascertaining of etiology, in the outlining of treatment procedures, and in the defining of probable consequences of treatment."

LEWIS (1936) observed that most treatises on growth neglected minor fluctuations in favour of major trends. He stated, "While major trends are of course important, minor fluctuations are likely to be of greater practical interest to the orthodontist, who is interested in the individual case."

MOORREES (1959) believed that a longitudinal growth analysis "affords an opportunity to study the development of individual children", whereas a cross-sectional growth study "yields a composite picture of a sequence of developmental stages at different chronologic age levels, which can apply to a specific individual only in a very general way." He further commented, "Nevertheless, longitudinal studies may yield no more profitable data in terms of the individual than cross-sectional studies unless specific methods are employed to determine the individual patterns of, and variations in,

developmental progress." WOODS (1950) similarly commented that "the advantage of longitudinal investigation is largely lost unless emphasis is placed on the individual, i.e., on the range of variation within the sample and on the growth behavior of dissimilar patterns." MOORREES and REED (1965) stated that "when instead of chronologic age the initiation of a growth or developmental event is used ... the increments or effects of the event can be determined more satisfactorily ... because differences in the chronologic age at which a specific phase occurs are neutralized."

The studies reviewed in this chapter are longitudinal investigations with the exception of SHAPIRO'S study. The samples described by MOORREES (1959), SILLMAN (1964), MOORREES and CHADHA (1965), and KNOTT (1972) do not strictly comply in that some of the series of casts recorded do not span the duration of the survey.

SILLMAN included in his sample children with good and poor occlusions and children who had been orthodontically treated. He believed that "the consideration of all factors which may influence the dentition would make the sample more closely resemble a true random sample". BROWN and DAUGAARD-JENSEN (1950) included a separate group of treated cases in their study but these are not included in this discussion. The remaining studies concern samples that at no time during evaluation underwent orthodontic treatment.

1.2.Intercanine Width Changes

LEWIS (1936) stated, "It is generally agreed among workers in this field that approximately five sixths of the mature width of the dental arch has been attained by the age of 4½ years". He illustrated arch increase in the canine region with a "smoothed curve of intercuspid growth". From this curve an initial quiescence of growth was noted between completion of the deciduous dentition and six years of age. From six years the curves for both the maxilla and the mandible show the beginning of an acceleration of growth, reaching a maximum at nine years and representing a second maturation point. Between nine and 10½ years, there is another quiescence, followed by another spurt, which reaches its maximum at about 13 years. He concluded, after observation of many growth curves, that "intercuspid growth is coincident with the eruption of the permanent incisors and cuspids. There is one period of accelerated growth beginning during the eruption of the incisors; and a second ... period of accelerated growth begins during the eruption of the cuspids." He added that "the essential factor in good alignment and occlusion of the permanent teeth of the anterior segment of the arches is not the occurrence of deciduous incisor spacing before the eruption of the permanent incisors, but growth adjustments during or after eruption." Adjustment in alignment and occlusion was considered to take place during a period of quiescence in growth.

COHEN (1940) similarly recorded a "consistent and definite growth period ... in the cuspid region between the ages of 5½ and 8½, or during the period in which the lower permanent

teeth are erupting." However, unlike LEWIS' study, COHEN'S sample (longitudinal study of 28 children from 3½ to 13½ years) showed no further lateral development in the cuspid area after 8½ years of age. An incidental observation from this study was that the girls' arches were narrower in the anterior or cuspid region than the boys' are, but the girls' arches were wider in the posterior, or first permanent molar, region. In conclusion, COHEN stated that the greatest lateral growth in the dental arch occurs in the cuspid area with the greatest increase in this region occurring during the eruption of the permanent incisor teeth.

From COHEN'S results, the amount of intercanine increase prior to permanent incisor eruption (3½-5½; 0.6 mm) and during eruption (5½-8½; 2.5 mm) were derived. CLINCH (1951) recorded remarkably similar results (0.4 mm and 2.6 mm respectively) for the same periods from her study of 61 sets of serial models of children between three and eight years of age.

SHAPIRO (1941) using a cross-sectional sample of 544 found that the lateral dimension between the canine teeth reached 86.9% of its final dimension at age 5 years. A further 5.3% increase was recorded between 5 and 7 years, 5.6% between 7 and 13 years, and 2.2% between 13 and 17 years, after which no further growth was recorded. The two latter increases differ markedly from the findings of COHEN who found no increase after 8½ years of age.

BROWN and DAUGAARD-JENSEN (1950) reported a decrease of inter-canine width in 18 out of 24 untreated cases in a longitudinal study from early teens to early twenties. The average decrease was 0.88 mm, with a range of 0.2 to 2.6 mm. Four cases showed an average increase of 1.3 mm (range 0.2 to

2.0 mm), and 2 showed no change. These results indicate an average decrease in inter-canine width for this sample, which is inconsistent with the 2.2% increase in this dimension reported by SHAPIRO for a comparable sample.

WOODS (1950) found that the mean distance between the lower canines remains constant from 3 to 6 years of age, after which it decreases until the age of 9. It then gradually increases until age 15, when it slightly exceeds that at the third year. Frontal cephalograms were used in this study, rather than direct measurement from dental casts as in previous studies. Once again a disparity between results is evident. Whereas LEWIS found an acceleration of growth of the inter-canine region from 6 to 9 years of age followed by a quiescence from 9 to 10½ years, WOODS found a decrease followed by a gradual increase for these two periods respectively.

BARROW and WHITE (1952), like LEWIS, COHEN, and SHAPIRO found that the intercanine width increased from 5 to 8 or 9 years of age. The collective evidence of these authors would seem to refute the decrease reported by WOODS for this age group. The study of BARROW and WHITE was consistent with that of BROWN and DAUGAARD-JENSEN but inconsistent with that of SHAPIRO in that they found intercanine width had decreased in most cases after 14 years of age, whereas a slight increase was reported by SHAPIRO and a slight decrease derived from BROWN and DAUGAARD-JENSEN.

MOORREES (1959) detailed an exhaustive study of 184 children between the ages of 3 and 18 years. Mean annual increments for males and females (samples varying from 13 to 40 children) for intercanine width were recorded. He found that "the mean

distance between the canines increases continuously and markedly after 5 years of age to a maximum at 10 years in the males and at 9 years in the females. Following this growth phase, around the mean age of emergence of the permanent mandibular canines, there is a slight decrease in the average intercanine distance. Little change occurs after 12 years of age."

MOORREES and CHADHA (1965) studied spacing and crowding of the incisors in the sample previously investigated by MOORREES and supplemented by 48 more cases. This study revealed that crowding in the mandibular incisor segment on eruption of the incisors amounted to 1.6 mm in males and 1.8 mm in females. This discrepancy was moderated to 0.2 and 0.5 mm in males and females respectively by increase of intercanine width and arch length during the eruption of the lateral incisors. They concluded that "no great relief of crowding in the incisor segment can be expected after the complete eruption of lateral incisors. One can, however, prevent mesial migration of permanent first molars and thereby make provisions for the utilization of the leeway space by the anterior teeth."

SILLMAN (1964), from a comprehensive longitudinal study from birth to 25 years, found that intercanine width increased 3.5 mm in the first two years in males. A steady increase was recorded until 12 years, and thereafter no change was noted. In females no change was recorded after completion of intercanine increase at 16 years of age. These findings showed some similarities to those of SHAPIRO.

KNOTT (1972) studied arch width increase in individuals who had not received orthodontic treatment in a longitudinal study from the deciduous dentition to adulthood. Intercanine width

was found to increase from the deciduous dentition (average age 5.4 years) to mixed dentition (average age 9.4 years) by 2.86 mm, i.e. during the period of eruption of the permanent central and lateral incisors. From mixed dentition to permanent dentition (average age 13.6 years) a further increase of 0.34 mm was recorded. From the permanent dentition to the "young adult" recording (average age 25.9 years) a reduction in intercanine width of 0.09 mm was recorded. She concluded that "for most individuals, maximum bicanine diameter of both arches showed little change after the stage of permanent dentition was attained. In the mandibular arch, increase in this width occurred largely before the eruption of the permanent canine teeth."

SINCLAIR and LITTLE (1983) investigated the mandibular dentition of 65 "orthodontic normals", based on individuals with dental and skeletal Angle Class I relationships, judged to have clinically "good" occlusion, who had undergone no orthodontic treatment of any sort. They found a reduction in intercanine width from mixed dentition (average age 9 years) to early permanent dentition (average age 13 years) of 0.31 mm followed by a further reduction of 0.44 mm from early permanent dentition to early adulthood (average age 20 years). Constriction of the male group was gradual over the entire period while the females had the major change during the permanent dentition stage. They concluded that "intercanine width remains virtually unchanged after the eruption of the permanent dentition". For comparison of these results with the treated sample of LITTLE, WALLEN and RIEDEL (1981), mean annual change of intercanine width was calculated for both samples and found to be -0.19 mm for the treated

sample compared to -0.06 for the untreated sample. The reason for the significantly greater decrease in intercanine width for the treated group could not be validated given that "many of this sample were not expanded", but it was postulated that "untreated cases will show continuing loss of width with time and may very well approach the state noted in LITTLE'S sample by the fourth and fifth decade of life."

4.1.3.Summary Of Intercanine Width Changes

Table 1 has been formulated to facilitate direct comparison between the studies reviewed, and analysis of the conclusions made by the respective authors. Sample size and age group are given in the second column. Following this the results are summarised chronologically as described by the original author according to the time scale (years) indicated in the title line. These figures (mm) were either taken directly from the results given, or derived from those available.

During the deciduous dentition LEWIS, WOODS, and BARROW and WHITE found no change in intercanine width, whereas COHEN, CLINCH, MOORREES, and SILLMAN indicated some increase.

During the transitional period from the deciduous to mixed dentition LEWIS, COHEN, CLINCH, SHAPIRO, BARROW and WHITE, MOORREES, SILLMAN, MOORREES and CHADHA, and KNOTT all indicate an increase in intercanine width. LEWIS, COHEN, CLINCH, MOORREES, MOORREES and CHADHA, and KNOTT found this increase to be mainly coincident with eruption of the permanent incisors. LEWIS and BARROW and WHITE indicated that increase in this region is also evident when the permanent canines

erupt. MOORREES, however, found a slight decrease during eruption of the permanent canines. In marked contrast to these results, WOODS found that canine width decreased during the mixed dentition and increased during transition to the permanent dentition, resulting in an intercanine dimension only slightly in excess of that recorded at 3 years of age.

During early adulthood BROWN and DAUGAARD-JENSEN, BARROW and WHITE, KNOTT, and SINCLAIR and LITTLE found that there was a slight decrease in intercanine width. Contradiction persisted as SHAPIRO, MOORREES, and SILLMAN found no change during this period.

TABLE 1
INTERCANINE WIDTH CHANGES - GROWTH (mm)

AUTHOR YEAR	SAMPLE AGE	DECIDUOUS 0.....5	MIXED 10	PERMANENT 15	ADULTHOOD .....Yrs
LEWIS 1936	N/A 2-12 Yr	—— ——	No Ch 0	Incr. 2 / NC 0 / Incr 1	—— ——
COHEN 1940	28 3½-13½	—— ——	Inc 0.6	Incr. 2.5	No Change 0 / —— ——
SHAPIRO 1941	544 5-25 Yr	—— ——	Inc 1.7	Increase 1.8	Incr. 0.7 / No Ch 0
BROWN 1950 DAUGAARD-J	24 12-21Yr	—— ——			Decrease -0.44
WOODS 1950	28 3-15 Yr	—— ——	No Ch 0	Decr. -2.36	Increase 2.98 / —— ——
BARROW and WHITE 1952	51 3-18 Yr	—— ——	N/C 0	Incr 3	Not Avail. Not Avail. / Decr. -½/-1½ / —— ——
MOORREES 1959	184 3-18 Yr	—— ——	Inc 0.5	Increase 3.4	Dec -.2 / No Change 0 / —— ——
SILLMAN 1964	65 0-25 Yr	Inc 3.5	Increase Not Available		No Change 0
KNOTT 1972	35 5-26 Yr	—— ——	Incr. 2.86	Increase 0.34	Decrease -0.09
SINCLAIR & LITTLE 1983	65 9-20 Yr	—— ——		Decr. -0.31	Decrease -0.44

It is evident that there is wide variation of opinion concerning increase of the intercanine dimension. Most attention is focused on the period of eruption of the permanent incisors. BURSON (1952) studied intercanine width increase during this period with "specific reference to individual variability." He concluded, "The greatest increase in this dimension during this interval occurs during a period of accelerated increase. Although this spurt, in a study of averages, occurs between the ages of 5 and 8 years, a wide individual variation in time of spurt is observed."

MOYERS (1973) stated, "The intercanine diameter increases only slightly in the mandible, and some of this increase is due to the distal tipping of the primary cuspids into the primate space."

The weight of evidence seems to indicate that there is no natural increase in anterior arch width to aid alignment of crowded incisors during the period that orthodontic treatment is most likely to be undertaken. Significantly, intercanine width has been shown to remain constant or decrease slightly during this critical period.

4.1.4.Intermolar Width Changes

COHEN (1940) showed that "little lateral growth in the molar region" occurred between the ages of 6½ and 13½. In males the mean intermolar width at 6½ years was 35.0 mm and varied no more than 0.5 mm before a final mean width at 13½ of 35.0 mm. In females the intermolar width at 5½ years was 36.1 mm, reached a maximum of 37.4 mm at 11½ years before a final

recording of 37.0 mm at 13½ years.

SHAPIRO (1941) presented figures indicating significant increase in dimension "across the mandible in the region of the last molar teeth". He indicated a 5.3 mm increase from 5 years ("after eruption of the deciduous dentition"), to 7 years ("after the eruption of the first permanent molar"). This is misleading since, by his definition for this measurement, a more distal and broader segment of the arch was measured. However, he recorded a 5.0 mm increase from 7 years to 13 years ("previous to the eruption of the second permanent molar"), which presumably is a genuine increase across the same arch segment and significantly different from COHEN'S results. He then indicated an increase of 2.5 mm from 13 years to 17 years ("after the eruption of the second permanent molar") and 6.3 mm from 17 years to 25 years ("after the eruption of the third permanent molar"). Once again, these are not valid comparisons since they do not relate to comparable segments of the arch.

From the results presented by BROWN and DAUGAARD-JENSEN (1950), a mean decrease in intermolar width between 12 and 21 years of age of 0.1 mm was derived. This indicated stability for intermolar width over a critical period (with respect to timing of orthodontic treatment), contrary to the significant expansion for this dimension implied by SHAPIRO.

WOODS (1950), using frontal cephalograms, found that the distance between the lower molars decreases until the teeth come into occlusion. From complete eruption to 15 years of age, he stated that the intermolar width "may increase, decrease, or remain stationary." His mean figures revealed that from 7 to 15 years a 0.6 mm reduction occurred in males

and a 0.8 mm reduction occurred in females.

BARROW and WHITE (1952) found that from 7 to 11 years of age, the average increase in intermolar width in the mandibualar arch was 1.2 mm. From 11 to 15 years of age there was an average decrease of 0.9 mm which they attributed to "mesial drift of the first permanent molars after the loss of the primary molars". From 15 to 17 years more than half of the cases showed a continued decrease in intermolar width. They concluded, "Orthodontists, in planning treatment procedures, should expect moderate increase in width of the dental arches particularly in the anterior regions until the permanent canines erupt. After this time they should plan on some decrease in arch width in both the anterior and posterior regions."

MOORREES (1959) presented mean yearly intermolar width values from 6 to 19 years of age from his study of 184 children. The number in each sub-group, male and female according to age, in this analysis varied from 9 to 52. He found that the permanent mandibular first molars increase "during three growth phases in both sexes but only during the last one, beginning at 13 years of age in the males and at 11 years of age in the females, is the increase in this distance appreciable."

SILLMAN (1964) recorded an increase of 0.2 mm per year in intermolar width until eruption of the second molar. From 14 years on, there was no evidence of significant change in males and in females "the apparent decrease in both jaws from 16 years to the last age group provides no evidence of significance."

KNOTT (1972) took arch measurements posteriorly in the

second deciduous molar/second premolar region, rather than the first molar region as in the other studies reviewed. She found that "over the entire span of twenty years the least change was from width at the deciduous mandibular second molars to width at the mandibular second premolars." In males this dimension increased 1.4 mm from the deciduous dentition (average age 5.4 years) to the mixed dentition (average age 9.4 years), remained constant to the permanent dentition (average age 13.6 years), and then decreased 0.5 mm to the young adult stage (average age 25.9 years) for a net increase of 0.9 mm. Females followed a similar pattern, recording an initial increase of 1.6 mm followed by no change and a subsequent decrease of 0.3 mm at the respective stages of dental development for a net increase of 1.3 mm. It can be seen from these results that during the likely period of fixed appliance therapy, a slight decrease in arch width in this region should be expected.

DEKOCK (1972) measured intermolar width in 16 males and 10 females, at the first permanent molar, between the ages of 12 and 26 years and found a gradual mean increase of 0.9 mm in males and 0.3 in females over this period. He interpreted these figures as not significant for females over the entire 14 year period but there was a slight statistically significant increase in males from 12 to 15 years of age.

SINCLAIR and LITTLE (1983) recorded intermolar width at the at mixed dentition (age 9 years), early permanent dentition (13 years), and early adulthood (20 years). They found that males showed a small insignificant mean increase in this dimension over the entire study, whereas females showed a statistically significant loss in width. The male sample

increased 0.30 mm from 9 to 13 years of age, and 0.25 mm from 13 to 20 years of age. The female sample decreased 0.41 mm and 0.47 mm respectively over the two periods recorded. This would appear to be a consistent decrease in arch width (contrary to their assertion that "the majority of the decrease" occurred in the latter period) over the two developmental periods, and of doubtful clinical significance considering the likely timing of orthodontic treatment and retention. Their conclusion was that "intermolar width in general remained very stable with some degree of sexual dimorphism present."

4.1.5.Summary Of Intermolar Width Changes

Table 2 has been formulated to facilitate direct comparison between the studies reviewed. The values presented for intermolar width changes were either taken directly, or derived from those quoted in the study. KNOTT measured arch width across the second deciduous molar/second premolar region rather than the first permanent molar region. Some of the longitudinal studies by other authors commenced prior to eruption to the permanent molars and accordingly, the period prior to molar eruption is indicated as "U/E", i.e. uneruptedd. Separate male and female values are presented where comparison is warranted.

The most significant overall observation is that, with one exception, very little change in intermolar width occurs after eruption of the first permanent molar. SHAPIRO recorded at least 5 mm increase in arch width in this region, significantly more than the next highest increase of 2.4 mm

recorded by MOORREES. SHAPIRO also recorded the highest increase in intercanine width (see Table 1).

Intermolar width changes for male and female samples were similar, except MOORREES, who found slightly greater arch width increase in males, and SINCLAIR and LITTLE, who recorded a slight increase in males and a slight decrease in females.

It would seem that during the period when orthodontic treatment is usually undertaken (early to mid teens), it is unlikely that any clinically significant arch expansion will occur. A slightly decreased dimension may occur during this period.

TABLE 2
INTERMOLAR WIDTH CHANGES - GROWTH (mm)

AUTHOR YEAR	SAMPLE AGE	DECIDUOUS 0.....5	MIXED	PERMANENT 10		ADULTHOOD 15.....Yrs
COHEN 1940	28 3½-13½	— —	U/E U/E	Increase 0.7	Dec -.3	— —
SHAPIRO 1941	544 5-25 Yr	— —	Ref Txt	Increase 5.0		Refer to Text
BROWN 1950 DAUGAARD-J	24 12-21Yr	— —				Decrease -0.1
WOODS 1950	28 3-15 Yr	— —	U/E U/E	Decrease -0.7		— —
BARROW and WHITE 1952	51 3-18 Yr	— —	U/E U/E	Incr. 1.2	Decr. -0.9	Decr. N/A —
MOORREES 1959	184 3-18 Yr	— —	U/E U/E	Increase; Male 2.4 Increase; Female 1.5		—
SILLMAN 1964	0-25 Yr	U/E U/E	Increase 2			Male; No Chg F; Sl. Decr.
KNOTT 1972 (E/5)	35 5-26 Yr	— —	Incr. 1.5	No Ch 0		Decrease -0.4
DEKOCK 1972	26 12-26Yr	— —				Increase 0.7
SINCLAIR & LITTLE 1983	65 9-20 Yr	— —		M; +0.3 F; -0.4		Male; +0.25 Female;-0.47

4.2.MANDIBULAR GROWTH AND DEVELOPMENT

MOYERS (1973) indicated that growth at the median mental symphysis occurs in the neonate, but "by the second year the symphysis has closed, a feature of Man and the other primates." This was consistent with the descriptions of GOOSE and APPLETON (1982), who stated, "complete bony union to form a synostosis is not complete until the end of the first year after birth", and similarly, MOORE and LAVELLE (1974). From these accounts, it is evident that there is no potential for sutural growth in the mandible and hence no capacity for arch width increase by this means.

A model differentiating continued lateral growth of the mandibular body in relation to the dento-alveolar process was resolved by ENLOW and HARRIS (1961), who examined microscopically, entire transverse sections of human mandibles and mapped the distribution of endosteal and periosteal bone deposits. This allowed a detailed analysis of local directions of growth in each part of the mandible. They described growth of the mandible in terms of the "V principle" involving orientation of cortical plates which form a "V" configuration. The inner surface of the "V" faces the actual direction (or multiple directions) of growth, and receive the new deposits of bone. The outer, contralateral surface usually undergoes corresponding and simultaneous resorption, facilitating enlargement and movement in the direction of the wide end of the "V".

The mandibular body grows into successive areas previously occupied by the posteriorly moving ramus. The posterior part

of the body becomes lengthened and is converted from the former ramus of an earlier growth stage by structural remodeling. The "V principle" applies since new bone deposits are added onto the lingual side of the V-shaped posterior body and anterior ramus as these areas move in a posterior direction. The mandibular body and its dental arch lie on an axis which is positioned medial to the ramus. Deposition of periosteal bone on the lingual surface, which faces the posterior and cephalic direction of growth, brings the basal part of the "V" toward the midline. Thus, the tuberosity is moving in a lingual and posterior direction, as the body lengthens, by periosteal addition onto its lingual surface. Below this area of lingual deposition is an area of periosteal resorption of the lingual cortex continuous with the broad zone of periosteal resorption found along the posterior and basal margin of the ramus. This endosteal-growing fossa allows the body to keep pace with the over-all increased dimensions of the entire mandible. Buccally, periosteal deposition results in the formation of the trihedral eminence on the buccal side of the posterior mandibular body.

Therefore, it is evident that, although only minimal increase in arch width occurs beyond the mixed dentition period (see Tables 1, 2), particularly in the canine region, growth and development can proceed such that the mandible assumes adult dimension and proportion without effecting arch dimension in the canine and molar regions.

CHAPTER 5

PERIODONTAL CONSIDERATIONS

5.1.INTRODUCTION

REITAN (1969) emphasised the significance of periodontal and gingival fibres in maintaining treatment stability, stating, "Among the factors that may cause relapse following orthodontic tooth movement, abnormal muscle function, occlusal stress, and especially contraction of displaced fibrous structures are the most important. In some cases the effect of fibrous tissue rearrangement may be observed even after several years." He considered that "lower incisors, canines, and second premolars tend to migrate toward their original position more frequently than other teeth." His retention strategy was "based on the overcorrection principle" for extended periods "because when individual fibers are stretched, they will become permanently elongated with retention."

Although EDWARDS (1970) was concerned with the mechanism and control of rotational relapse, the same principles can be applied to tooth movement in general. He considered that osseous structures have little difficulty adapting to a new tooth position, but "the exact mechanism by which fibres in the periodontal ligament permit extensive orthodontic rotations of teeth is not clear." The existence of an "`intermediate plexus' in which could occur the dissolution of fibre connections, the production of new fibres, and the

formation of new functionally adapted fibre connections" would be convenient, but has not been routinely observed.

ARNIM and HAGERMAN (1953) demonstrated "a band of compact connective tissue encircling the teeth within the marginal gingiva" and suggested that this arrangement indicates "a significant role in maintaining the tone of the marginal gingiva and its close adherence to the neck of the tooth." STUBLEY (1976) described transseptal fibres as "the gingival group of periodontal fibres which are firmly embedded in the cementum at the amelocemental junction and which bind adjacent teeth together across the bony septum". He noted that their durable nature and resistance to resorption has been reported throughout the dental literature. M^c^COLLUM and PRESTON (1980) described, from previous literature, the connective tissue fibres of the supra-alveolar system which join the attached gingivae to the alveolar bone and cementum of the teeth. The dentogingival groups of fibres attach the marginal and attached gingivae to the teeth, while the transseptal fibres originate in the cementum of adjacent teeth in the dental arch and traverse the interdental septa. They included in this system the circular fibres and the vertical and horizontal fibre groups.

The fibres of the periodontium and gingival tissues have been implicated in orthodontic relapse, and the fibre groups identified. The contribution of the relevant fibre groups, their structural significance, and the mechanisms facilitating movement and causing relapse have stimulated much investigation. In this context, the periodontal structures are relevant to further understanding orthodontic movements and relapse. REITAN (1959) found that apical fibres of the

periodontal ligament are completely rearranged within three months, and principal fibres within five months, whereas the supra-alveolar fibres were still only partly rearranged after eight months. Therefore the supra-alveolar fibres are the significant factor under consideration.

5.2.THE SUPRA-ALVEOLAR FIBRE NETWORK

ERIKSON et al (1945) investigated transeptal fibres using block dissections from two live human subjects. He found that "elongated transeptal fibres appear in the spaces created by tooth extraction", and when teeth adjacent to extraction spaces are brought together, "the transeptal fibres relax, coil, and then become compressed". He also reported resorption of bone, cementum, and dentine, crushing injuries to the periodontal membrane due to compression, and resistance to resorption of these fibres during space closure. THOMPSON et al (1958) also considered that "the collagenous connective tissue fibres are relatively inert" and presented evidence indicating that the disruption of these fibres above the alveolar bone aids retention after orthodontic tooth movement. THOMPSON (1959) later implicated supracrestal fibres in the forward movement of erupted third molars as traction is applied to second molars, proclination of retracted incisors, retention of vertical overbite, and relapse of buccal crossbite, arch length increase and intercanine width expansion.

REITAN (1959) noted that the major group of periodontal fibre bundles runs from the root surface to the inner alveolar

surface, whereas the free gingival fibres are attached in the gingival soft tissues and the periosteum. He found that rotating dog incisors caused a marked displacement and stretching of the free gingival group. Because these fibres are continuous with the whole fibre system, stretching caused "displacement of fibrous structure at some distance from the rotated tooth", due mainly to the fibre group attached to the lingual or labial surfaces of the root. Since new bundle bone and osteoid tissue were found arranged in tongue-like spicules along stretched fibres, REITAN concluded, "apposition of new bone is stimulated by the traction exerted by fibre bundles. This traction will also stimulate formation of cellular cementum along the root surface." In the apical region the supporting fibres were arranged obliquely. After retention of 232 days, it was found that periodontal fibres of the apical and middle region of the teeth had completely rearranged, whereas fibres of the marginal region "still remained stretched in accordance with the previous movement of rotation", particularly "fibre bundles attached to the labial and lingual surfaces of the root."

REITAN (1960) noted the presence of elastic fibres in the supra-alveolar tissue, along with interlaced free gingival fibre bundles. If these fibres are stretched during tipping movements and then released to allow relapse, contraction of the fibres "was strong enough to produce hyalinized tissue" at the apex and in some instances at the alveolar margin on the former tension side. From clinical observation (REITAN, 1967), he noted the tendency of lingually tipped lower canines, and proclined upper lateral incisors in typical Class II division 2 cases to migrate toward their original

position following treatment. This migration was considered to occur, not as a result of muscular imbalance, but due to a "tendency toward posttreatment contraction of fibrous tissue ... the fibre bundles, notably the supra-alveolar structures, tend to rearrange themselves according to the original growth pattern". Later, REITAN (1969) indicated "some variation between the types of fibrous tissue in various persons of the same age group" and the influence of the age factor. He also considered that supra-alveolar fibres containing "oxytalan and elastic fibres, increase in thickness as a result of function and stretching" and are rearranged at a slower rate than principal fibres due to a "scarcity of new cells".

EDWARDS (1968) noted in the literature one consistent observation: "the supracrestal connective tissue fibres, whose length and directon are not altered by an ever-changing osseous attachment, are extremely slow to adjust to orthodontic movements of the teeth." He used a tattooing technique in dogs to demonstrate that the attached gingiva, especially the marginal gingiva, is "pulled along with the tooth as it is rotated". He found that fibres of the gingiva remain attached to the tooth during orthodontic rotation, resulting in displacement of the gingiva in the direction of tooth movement. Gingival and transseptal fibres remained taut and oriented in the direction of rotation after five months of retention whereas those attached to osseous tissue are rapidly reorganised. It was not clear how "fibres of the periodontal ligament permit extensive orthodontic rotations of teeth". Three mechanisms were proposed to facilitate periodontal adaptation to tooth movement: (1) Groups of fibres might divorce themselves from a parent bundle and combine with

another neighboring fibre bundle. (2) Progressive osteogenic, and to a lesser extent cementogenic, activity may play a role in the shortening of extended fibres and in the reattachment of new fibres developed during tooth movement. (3) The stretching of the wavy collagen fibres and reorientation of their directional morphology permits a certain amount of tooth movement. Finally, "elastic" oxytalan fibres were "more prevalent in the areas of the periodontium most subjected to mechanical stress - the free gingival margin and the transseptal regions", and increased in number and definition during orthodontic treatment.

EDWARDS (1969), again using the tatooing technique, demonstrated the effectiveness of "a simple surgical method of severing all supracrestal fibrous attachment" to derotated teeth.

BRAIN (1969) considered that free gingival fibres are inelastic, travel in a wavy line, and are resistant to rearrangement and reorganisation following the movement of teeth. They are "attached to and terminate in the lamina propria of the gingiva and, during tooth rotation, cause these gingival tissues to be displaced." Consistent with previous authors, he suggested that these fibres may contribute to post-retention relapse. From his study, he concluded that "the transsection of the free gingival fibres, in conjunction with an optimal period of retention is a valuable adjunct in the retention of orthodontically rotated teeth." He also found that the nonsurgical control teeth consistently demonstrated more areas and a greater amount of cementum and bone resorption than was observed on the surgical side. This was attributed to the additional bone and cementum

reorganization required during relapse.

PARKER (1972) described transseptal fibres as "ligament-like fibres ... firmly embedded in cementum along the entire convexity of the cementoenamel junction", traversing between the proximal cervical aspects of the teeth. He believed that "the arrangement of these fibres indicates their need and function in maintaining mesiodistal relationships between neighbouring teeth and in stabilizing the tooth against separating forces." He further noted that when connective tissue fibres under stress attach to soft tissues, there is apparently no mechanism for their physiologic rearrangement. Where bone serves as an attachment, readaptation is made possible by bone resorption and deposition. His study involving premolar retraction in Macaca rhesus monkeys indicated that "transseptal fibres are probably the major cause of relapse of orthodontically moved teeth." Transsection of free gingival fibres, paralleling of tooth roots, and adequate retention time had a positive effect on the stability following retraction. Coiled transseptal fibres between approximated premolar and molar teeth were described as "`football shaped,' ballooning out over the crest of the ridge." Evidence of "very strong compressive forces" active in this area was indicated by extensive breakdown of the alveloar crest. Staining procedures revealed that collagen is the major constituent of the periodontal membrane and "the presence of an intermediate plexus was not conclusive". No elastic fibres were found. Oxytalan fibres were found throughout the periodontal membrane, particularly in the transseptal fibres. They attach to the cementum just apical to the cementoenamel junction, follow the configuration of the

collagen fibres, and become less concentrated as they approach the alveolar crest.

PICTON and MOSS (1973) implicated transeptal fibres in "approximal migration" of teeth. This was described as the tendency of teeth in mammals to migrate towards a common centre, thus maintaining approximal contact, which manifests in Man as mesial drift. They found that the removal of these fibres in Macaca irus monkeys at two week intervals significantly reduced or eliminated approximal drift. They subsequently found that when the lower molar teeth were divided through the bifurcation, the mesial and distal roots drifted apart unless the transseptal fibres were removed (MOSS and PICTON, 1974). MOSS (1975) reported that "observation of serial sections of teeth in certain carnivores has shown the absence of transseptal fibres between teeth which are spaced and their presence between teeth which are in contact." These findings, along with the systematic elimination by MOSS and PICTON of mechansims proposed by other authors, i.e. muscle forces, occlusion, maxillo-mandibular inclination, and the axial inclination of teeth, further validated their theory that the mechanism for approximal migration is located in the transseptal fibre system.

MOSS and PICTON (1982) removed proximal contacts between pairs of teeth in Macaca fascicularis monkeys and recorded short term approximating tooth movement with a capacitance transducer. They intrepreted this finding as substantiating the supposition that "the tractional force is in the approximal tissues and that it is held in check while approximal contacts are present." Evidence reported by other authors has determined that fibroblasts are capable of causing

contraction and are polarized in the transseptal fibre system of rat molars. These cells have also been reported to migrate into areas of trauma. MOSS and PICTON concluded, "On the basis of this range of evidence from studies of young fibrobalsts, it seems reasonable to suppose that fibroblasts in the transseptal fibre system provided the traction force".

M^c^COLLUM and PRESTON (1982), using attached gingiva tattoo marks, recorded the amount of gingival relapse or recoil that occurred following retraction and retention of maxillary canines in first premolar extraction cases. A "circumferential fibre cut", with a vertical incision along the palatal and buccal gingival cleft, with or without papillectomy of the accumulated gingival tissue was performed to facilitate gingival recoil. However no recoil was evident, which was considered to indicate "some adaptation of the gingival soft tissue to new tooth positions." They further concluded, "This adaptation would reduce, to some extent, the role which the gingival tissues are said to play in orthodontic relapse." However, since the supracrestal fibre network is presumably incised when the attached gingiva is relieved, any conclusions derived from their observations and applied to the fibrous component of the "gingival soft tissue" would not be valid.

5.3.TRANSSEPTAL FIBRES - THE IMPLICATIONS

ERIKSON et al (1945) concluded that approximated teeth will separate after retention due to the space requirements of coiled and compressed transeptal fibres. Therefore they

considered it to be biologically unsound to expect good proximal contact following space closure after extraction. Transseptal fibres were considered capable of moving teeth to which they are attached. HUCKABA (1952) believed that "the location and attachment of these fibres would indicate that they serve to maintain the mesiodistal relationship of neighbouring teeth and in stabilizing the teeth against separating forces." THOMPSON (1959) suggested that the migration of teeth in periodontal disease might be similarly explained.

REITAN concluded, "Among the factors that may cause relapse following orthodontic tooth movement, abnormal muscle function, occlusal stress, and especially contraction of displaced fibrous sturctures are the most important." He demonstrated that the principal fibres of the periodontal ligament are rearranged after a certain retention period, whereas the supra-alveolar structures may remain displaced and stretched for a longer period. He believed that overcorrection is advisable to allow for some relaxation of displaced supra-alveolar fibres and suggested retention that provides a certain degree of individual tooth movement.

Evidence has been presented by THOMPSON et al, BRAIN, EDWARDS, PARKER, and PINSON and STRAHAN (termed "pericision") advocating various surgical procedures of the periodontium to enhance orthodontic stability. They consistently indicated that the gingival fibres were responsible for orthodonic relapse.

STUBLEY (1976) stated, "Transseptal fibres do not contain elastic tissue; they are made of collagen and the motive power that they exert comes from the tiny coils into which they

contract as they mature. The force generated varies from individual to individual, being in some cases barely sufficient to maintain contact and in others strong enough to cause overlapping and rotations." EDWARDS (1968) described "elastic" oxytalan fibres in the periodontium of dogs which become larger and more numerous during orthodontic movement. PARKER (1972) demonstrated oxytalan fibres in the periodontium of monkeys but found no evidence to indicate their specific function. He suggested that, since they were concentrated in areas of stress, they might function "as a safeguard against abnormal forces causing separation and destruction of tissues." However, SIMS (1976) observed reconstruction, adaptation, and remodeling of the oxytalan system, "not merely increase in number during orthodontic movement." This was considered to refute "the concept that oxytalan fibres are stretched by orthodontic movement and subsequently contribute to relapse by elastic rebound." He believed that the oxytalan fibres could participate in a regulatory mechanism to control vascular flow.

MOSS (1975) stated that the transseptal fibre system is important in the mesial migration of teeth and considered that "the teeth are joined together by a system which is under tension." He postulated that fibroblasts provide the traction force. TEN CATE (1985) considered that all fibroblasts have the potential to contract and provide a force, and was critical of the concept of the "myofibroblast" as a specific entity. He concluded, "the fibroblast exhibits contractile properties that are used in scar tissue contraction and, possibly, tooth movement." He also noted that "the fibroblast is able not only to synthesize a wide range of products

continually, but also to degrade them simultaneously (collagen, for example)."

From evidence presented in the literature, it is apparent that the supra-alveolar fibre system is (1) partially responsible for the maintenance of equilibrium and implied dental arch stability (PROFFIT, 1978), (2) provides resistance to orthodontic movements, and (3) significantly contributes to relapse following orthodontic treatment. One component, the transeptal fibres, has been strongly implicated in mesial migration.

CHAPTER 6

THE BEGG TECHNIQUE

6.1.BEGG PHILOSOPHY

The Begg light-wire technique was originally presented by BEGG (1956) as "a technique for the application of optimum forces for tooth movement by using a single round stainless steel arch wire 0.016 inch, and even less, in diameter" enabling bodily, torquing and tipping movements of teeth. He proposed that the use of thin round steel arch wire eliminates the use of excessively high forces that are exerted by rectangualr arch wire, reduces treatment time due to rapid tooth movement, and employs forces that are easily controlled. The principle of differential tooth movement is used to intrude and/or retract anterior segments while conserving or manipulating posterior anchorage. Consequently, differential optimum forces facilitate reciprocal simultaneous movement of all groups of teeth.

BALDRIDGE (1973) summarised the distinguishing features of the Begg philosophy as:-

1. It is accepted that "all teeth migrate mesially and occlusally throughout life in an oblique direction." Treatment simulates this natural tendency and is therefore facilitated by controlled mesial movement of posterior teeth. For this reason, the use of extraoral anchorage is precluded.

2. The concept of maintaining a full complement of teeth to achieve normal occlusion is considered a fallacy. BEGG (1954) based his extraction philosophy on his observations of Stone-Age Man's dentition.

3. It is recognised that "often the individual, through evolutionary selection has acquired larger teeth than can be accommodated within his dental arches."

4. The movement of all teeth toward the position they are to occupy at the termination of fixed treatment proceeds simultaneously from the start of treatment.

5. Treatment in the mixed dentition is limited to some Class III cases and extreme Class II division 1 cases. Serial extraction is avoided.

6.2.ATTRITIONAL OCCLUSION

An account of BEGG'S (1954) principles of attritional occlusion as derived from Stone Age Man's dentition and substantiated by that of the Australian aboriginal has been presented in Chapter 2. However, SIMS (1964) emphasised, "since ... we are dealing with the occlusion of Civilized Man and not the dentition of Stone Age Man, it is obvious that certain compromises must be made. There is no longer a harmonious sequence of events producing arch reduction and anatomically correct occlusion." He further implicated the evolutionary reduction in jaw size (quoting Krogman, 1963),

particularly in the mandibular anterior region, as a factor complicating lack of attrition. Therefore, any attempt to move the incisal segments further forward, consistent with the principles of mesial migration as applied to the buccal segments, will result in instability. The compromise arises in aligning the incisal teeth back on basal bone. To facilitate this treatment objective, SIMS justified extraction therapy based on the following rationale:-

1. It simulates to some degree the natural loss of tooth substance which should take place by attrition.
2. It balances discrepancies between tooth size and evolutionary alveolar bone reduction.
3. It affords a means of masking severe anteroposterior jaw malrelationships.

6.3.DIFFERENTIAL FORCES

BEGG (1956) obtained differential movement based on the principle that "for moving anterior teeth with small root surface area, relatively light arch wire and rubber ligature forces produce the most rapid movement with the least disturbance to tooth-investing tissues" while leaving larger-rooted, posterior anchor teeth almost stationary. Conversely, anterior teeth can operate as an anchor unit while posterior teeth move rapidly by using relatively large forces. BEGG (1977) believed that the principle of differential forces was an integral part of his light wire technique, and considered that the findings reported by STOREY and SMITH (1952) "confirmed the results of his clinical

experiences."

STOREY and SMITH found that 150 to 200 gms represents an optimum range of force which should be used to produce a maximum rate of retraction of the mandibular cuspid without any movement of the anchor unit (first molar and second premolar) in first premolar extraction cases. As the retraction force was increased to approximately 500 gms, canine movement decreased and approached zero while appreciable movement of the anchor unit occurred. Below the threshold force levels, i.e. 150 gms for the canine and 300 gm for the anchor unit, no tooth movement was evident. They considered that this was consistent with the root surface ratio of canine to anchor unit of 3:8, and validated the concept of undermining resorption reported by Sandstedt in 1904 and confirmed by Schwartz in 1932.

6.4.THE LIGHTWIRE APPLIANCE

6.4.1.Arch Wire Material

BEGG (1977) considered that the 0.016 inch round austenitic stainless steel wire produced by A.J.Wilcock was best suited to his technique because it combined high resiliency with toughness. The development of Wilcock's heat-treated, cold-drawn wire was fundamental to the success of the Begg technique.

6.4.2.Attachments

SIMS (1964) described the bracket attachments used on the stainless steel band material as "modified ribbon arch brackets which must permit application of the principles of single point attachment to allow simple tipping of the teeth without any binding or friction whatsoever between arch wire and bracket."

6.4.3.Buccal Tubes

The molar bands are fitted with round buccal tubes of 0.036 inch internal diameter and 0.250 inch length. Flat oval molar tubes may be fitted to accept doubled-back arch wires where greater molar control is required.

6.4.4.Lock Pins

One-point safety lock pins are used during the first stage of treatment in conjunction with 0.016 inch arch wire. The shoulder on the labial surface of the head rests on the bracket to prevent impingement of the pin on the arch wire. The body of the lock pin reduces the arch wire slot to 0.016 inch for maximum rotational control during Stage I. The body of second stage lock pins is reduced to provide a slot of 0.020 inch to accept the larger arch wires normally used during Stage 2. Hook lock pins are used on all teeth that do not require mesiodistal uprighting during Stage 3 and assure positive locking of torqueing and main arch wire. High Hat lock pins can be used during any stage when vertical elastics

are to be worn.

6.4.5.Adjuncts

Latex or rubber elastics of various thickness and size are used depending on force requirements. Typically, a 3/8 inch or 5/16 inch x 2 oz elastic will deliver 60 to 70 gms of intermaxillary force. 2 ounce, or heavier 3½ oz elastics may be required for intra-arch traction.

Mesiodistal uprighting springs and spring pins, two or three coil and varying in gauge, are used mainly in Stage 3 but can be used earlier in treatment to augment anchorage.

Auxiliary torquing arches are used in Stage 3 which can deliver labial or palatal/lingual torque to one or more teeth. As with spring pins, the gauge generally used is 0.014 inch, but lighter wires (0.012 inch and lighter) may be preferred.

6.5.TREATMENT STAGES

BEGG (1975) described his technique in terms of three separate stages "that must not be allowed to overlap." The main consideration in making this distinction is efficient anchorage control. The tooth movements outlined below are done simultaneously.

6.5.1.Stage 1

1. Dental alignment and overcorrection is achieved by simple tipping movements.
2. Anterior spaces are closed.
3. Rotations of all teeth are overcorrected.
4. Deep anterior overbites are overcorrected to open bites, Class I and Class II anterior teeth are positioned and maintained edge-to-edge. Overbite is established for Class III malocclusions.
5. Open bites are overcorrected where possible to establish overbite.
6. Anteroposterior occlusal relations of the crowns of all teeth are overcorrected in Class I and Class II maolcclusions until the posterior teeth reach almost Class III relations. Class III maolcclusions are similarly overcorrected to almost Class II relations.
7. The crowns of the upper and lower anterior teeth are allowed to tip in response to arch wire and elastic force.
8. Upper and lower arches are co-ordinated.
9. Extraction spaces reduce.
10. Crossbites are corrected.
11. The axial relations of the anchor molars are corrected and free mesial tipping of these teeth is prevented.

6.5.2..Stage 2

The primary mechanical objective of Stage 2 is the simultaneous closure of remaining extraction spaces. All overcorrections achieved in Stage 1 are maintained. Facial

esthetics and profile considerations along with skeletal limitations determine anchorage manipulation and the balance between anterior retraction and mesial molar movement. In this regard, Stage 2 is a diagnostic stage. Midline correction should occur as space closure proceeds provided the molars and premolars are established in a Class I relationship. If a midline discrepency exists, differential forces from opposing intra-arch traction due to unequal extraction spaces will centre the midline.

6.5.3.Stage 3

The axial relations - labiloingual, buccolingual and mesiodistal - of all upper and lower teeth are simultaneously overcorrected in the final stage of treatment. Hence, Stage 3 is concerned mainly with root movement. Overcorrections achieved in Stage 1 are maintained in Stage 3 and during retention where deemed necessary. Treatment is finished simultaneously in both arches and the appliances are removed from both arches on the same day.

6.6.EXTRACTION TREATMENTS

6.6.1.Diagnosis

WILLIAMS (1969) maintained that favourable soft-tissue balance and harmony in the lower third of the face would be achieved if the incisal edge of the lower incisor is brought to a position at or near the AP line. With this objective in

mind, he presented the following treatment phenomena to be evaluated "in order to decide what, if any, arch-length adjustments are appropriate and what use to make of differential forces in order to reach this treatment goal":-

1. Alignment of crowding in the lower arch.
2. Levelling the curve of Spee.
3. Correction of the molar relationship.
4. Anchorage requirements - for retraction of the upper anteriors and reduction of apical base difference.
5. Forward growth of the mandible relative to A point and concomitant translation the lower incisor.

If the lower incisor is not advanced too far ahead of the AP line by any of these treatment effects, then non-extraction treatment is indicated. The degree to which any of the above, individually or combined, will advance the lower incisors beyond the AP line, determines which teeth should be extracted.

WILLIAMS used the average root surface areas determined by Freeman, 1965, to derive relative resistance values of upper and lower, anterior and posterior arch segments. The amount of anterior retraction was condsidered to be directly related to the ratio of these root surface areas. In non-extraction treatment, the ratio of anchorage resistence in the lower arch to upper arch retraction was calculated to be 100 to 109. If first molars are extracted, a ratio of 100 to 400 was calculated, indicating "that the second molars will move four times as far forward as the upper incisors and point A will move posteriorly."

This somewhat simplistic model, which may not entirely account for root morphology and makes no reference to bone

density, was later tested by WILLIAMS and HOSILA (1976). They found that moving the extraction site in the lower arch distally reduces the potential for combined upper and lower incisor retraction. The movement of lower incisors for different extraction treatments relative to the AP line was not given.

6.6.2.First Premolar Extraction

BEGG (1975) believed that four first premolars "should be extracted when extractions are indicated" because (a) the first premolars are closer to region where crowding is most liable to occur, and (b) appliance therapy is more easily and successfully performed if four premolars close to the anterior teeth are removed. The extraction of first molars was considered to be not ideally suited to the technique as ten teeth in each arch would then require distalisation, contrary to BEGG'S (1954) philosophy of attritional occlusion and mesial migration. Similarly, he believed that second premolars should not be extracted instead of first premolars unless carious or faulty in their formation. Relapse of anterior teeth is more likely "because the mesial migration force from eight teeth is more powerful than from six."

BEGG advocated the extraction of four first premolars and four first molars in those patients who have an excessive amount of tooth substance relative to jaw size. An estimated 2% of cases would require these extractions, particularly considering cases that (a) cannot be excellently treated by four first premolar extractions, (b) will have some relapse after treatment, and (c) will have impacted third molars

unless eight teeth are extracted before starting orthodontic treatment.

Rarely, BEGG advocated the extraction of a lower incisor in "Class III malocclusions in which the lower incisors relapse to anterior crossbite unless a lower incisor is extracted."

6.6.3.Second Premolar Extraction

NANCE (1949) derived a rationale for elective second premolar extraction while dealing with congenitally missing second premolars. He considered suitable cases to be those "diagnosed as mild bimaxillary protrusion ... for which you might hesitate to extract the four first bicuspids" due to profile considerations during space closure. Some forward drift of the teeth is apparent which would be exacerbated by non-extraction treatment. In suitable extraction cases, "after crowding has been relieved, there remains space which must be closed either by excessive lingual tipping of the incisors or by forward movement of the posterior teeth." Forward movement of the posteriors is best controlled by moving molars into the extraction spaces of second premolars using first premolars, canines, and incisors as anchorage.

SCHOPPE (1964) was concerned that over retraction of the anterior teeth resulted in relapse tendencies, particularly in the form of spacing and excessive overbite. Facial profile changes may occur and increase as the case matures. He believed that second premolar extractions are indicated in cases where a proportionate harmonious facial contour is present, the lower incisor teeth are well related to the mandible and the mandible well related to other skeletal

parts, and moderate arch crowding exists with "indifferent mesiodistal occlusion".

"Borderline cases" with mild bimaxillary protrusion requiring 1-2 mm retraction, and mild Class II malocclusions "with fair muscle balance where arch crowding is not excessive" were also deemed suitable. For the latter, SCHOPPE advocated second premolar extractions so that upper incisor retraction is not complete when all upper spaces are closed, thereby creating the necessity for increased use of Class II elastics to ensure mesial movement of the lower molars.

HENRY (1967) related the degree of crowding to facial esthetics in differentiating premolar extractions. If crowding amounts to "less than half the width of a bicuspid in each segment, four second bicuspids are extracted if the facial esthetics permits." He noted that the face becomes less prominent with age, and perhaps young patients should be treated to a "slight fullness or protrusion of the lips knowing that future growth will improve and not mar the facial esthetics".

DE CASTRO (1974) considered second premolar extraction appropriate (1) where forward movement of 2.5 mm or more is required of the molars, (2) in the average extraction case where the patient does not require facial profile changes, (3) in cases of 5 mm. or more arch length descrepancy, and (4) where posterior crowding of second and/or third molars exists. Evaluation of soft tissues was emphasised, with particular reference to Holdaway's facial esthetic line.

THOMPSON (1977) listed the indications for second premolar extractions as:-

1. Good profile plus mild crowding.

2. Flat profile plus moderate crowding.

3. Class II division 1 arch relation on Skeletal I base with mild mandibular crowding.

4. Mild Class III arch relationship with mild crowding in the maxillary arch.

The advantages of this approach are"-

1. Preservation of facial contour and lip profile.

2. The maxillary first premolar was considered more esthetic alongside a canine.

3. There is less tendency for extraction spaces to reopen in the mandibular arch.

4. Rapid space closure reduces the possibility of buccal or lingual bone furrows in the extraction area.

5. "Round tripping" is avoided.

It must be emphasised that NANCE, SCHOPPE, HENRY and DE CASTRO did not stipulate the method of space closure employed with their respective Edgewise appliances. In interpreting their conclusions, consideration should be given to the greater potential of the Edgewise appliance to tax anterior anchorage than the Begg appliance during posterior space closure.

6.6.4.Non-extraction

BARRER (1969) considered that Begg principles can be applied to non-extraction cases whereas traditionally it was primarily an extraction procedure. He would ideally finish treatment with the lower central incisor on the AP line and the upper central incisor at 95 degrees to NS, with an ANB angle of not more than 5 degrees. Dictating the lower incisor relation to

AP, and therefore of diagnostic significance in contemplating extraction, are (1) unraveling dental crowding, (2) leveling the occlusal plane, (3) correcting the molars to a Class I relationship, (4) torquing requirements, and (5) growth of the mandible in relation to A point. He concluded, "Therefore, if our diagnostic evaluation shows that there is sufficient intra-arch space to position the teeth properly, or if arch length can be increased and dental correction obtained without violating the profile or AP line beyond acceptance, non-extraction therapy is indicated (and vice versa)." He noted that non-extraction treatment is successful almost in direct proportion to the rate of bite opening. The more rapidly this occurs, the less strain there is on the anchor units.

SWAIN and ACKERMAN (1969) indicated what they considered to be "two fallacies inherent in any concept that extraction treatment is required for most patients":- (1) The findings in Stone Age Man may not apply equally to all races, in every environment, in various degrees of civilized status. (2) These findings may not be relevant to mild malocclusions. Applying Begg mechanics to non-extraction treatment on the basis of these assumptions, they noted "one of the paradoxical but pleasant surprises of Begg non-extraction mechanics is that anchorage potential is often enhanced if the anchor molars have a mesial axial inclination at the commencement of treatment." A normal anchorage bend will cause beneficial distal tipping of the molar crowns into upright positions if combined with lighter than usual Class II elastic force. Net distal movement occurs because, although the influence of the anchorage bend simultaniously tends to tip the crown back and

the root forward, crown tipping is a rapid response while root tipping is a slow response.

CHAPTER 7

ORTHODONTIC TREATMENT AND MANDIBULAR ARCH WIDTH

(RELATED STUDIES - EDGEWISE TREATMENT)

7.1.INTERCANINE WIDTH

7.1.1.Studies Advocating Permanent Intercanine Expansion

WALTER (1953) investigated 102 non-extraction cases to determine whether or not teeth could be moved and held in desired positions which would be stable without resorting to extraction. Of the 102 cases selected, models were available for 34 of the cases immediately after active treatment, and models and/or direct measurements of ninety cases were made at intervals of 12 or more months following the removal of retaining devices. Thus, 34 "complete data" and 90 "partial data" cases were analysed. For the partial data cases, of the intercanine widths that increased, a mean expansion of 1.95 mm. was recorded, whereas a mean 1.02 mm. reduction was recorded for the cases where intercanine width reduced. The percentage of cases for this group in which the intercanine width was permanently expanded or reduced was not indicated. For the complete data cases the mean figures were 1.86 mm. and 0.77 mm. respectively. WALTER then assessed arch width measurements for the complete data cases and found that of the 32 sets of measurements taken for the mandibular canine, the movements were as follows :-

1. 6% showed intercanine width increase which was stable.
2. 44% showed intercanine width increase that was more than necessary. Subsequent post-retention adjustment by natural forces tended to return the canines to or toward their original positions.
3. 6% showed intercanine width increase which returned due to the adjustment of growth and function to their original position and cancelled the linear modification brought about by treatment.
4. 28% showed intercanine width increase which relapsed to a width less than the original dimension.
5. 13% resulted in intercanine width reduction which continued to reduce in the post-retention period.
6. 3% did not change intercanine width during treatment, but showed some reduction during the post-retention period.

In conclusion, he stated, "The findings of this investigation seem to indicate that the statement that the dental arch can not be permanently widened or lengthened, is incorrect."

WALTER (1962) later measured the mandibular intercanine and intermolar widths of fifty extraction and fifty non-extraction cases. The measurements in this study were taken before treatment, following completion of active treatment, and at least one year following removal of retainers for all cases included in the sample. As in the previous study (1953), tooth movements after active treatment were attributed to "adjustment which was produced by function and growth", rather than referred to as relapse. Accordingly, the same

diagrammatic representation of tooth movements was used to illustrate the results.

His results showed that in 62% of non-extraction cases the intercanine width was permanently increased (Orthodontic Movement +3.2 mm,. Adjustment -1.2 mm., Resultant +2.0 mm.), while in 36% of cases the intercanine width was reduced permanently (O.M. +0.1 mm., A. -1.1 mm. R. 1.0 mm.). The extraction group also showed a permanent increase of intercanine width in 62% of cases (O.M. +2.7 mm., A. -1.3 mm., R +1.4mm.) and a permanent reduction in 36% of cases (O.M. +0.9 mm., A. -2.2 mm., R. -1.3 mm.). Therefore in cases where intercanine expansion was obtained and maintained, extraction cases were just as likely to relapse (i.e. Adjustment) as non-extraction cases. In cases where the intercanine width was permanently reduced, a greater initial expansion was evident in extraction cases followed by a larger relapse to give a similar resultant intercanine reduction. It is apparent then, that not only were the extraction cases just as likely to relapse when expanded, but permanently reduced intercanine width in extraction cases resulted from greater initial expansion followed by an increased amount of relapse. Further analysis of his results showed that 56% of extraction and 56% of non-extraction cases were initially overexpanded during treatment and relapsed to varying degrees to give a resultant permanent expansion. Thus extraction did not reduce the incidence of relapse.

Although WALTER did not make any conclusions from this study other than to highlight the limitations of such investigations, permanent intercanine width increase was again demonstrated.

STEADMAN (1961) recorded the maxillary and mandibular intermolar and intercanine widths of thirty-one orthodontic cases before treatment, at the completion of treatment, and one or more years after termination of retention. The types of malocclusion were not indicated and the figures (to the nearest millimeter) were presented in tables which were at times confusing due to inaccurate labelling and tabulation. He noted a maximum increase of intercanine width from before treatment to post-retention of six millimeters, to a decrease of as much as three millimeters. In some cases the increase gained during treatment continued to increase, whereas in other cases the increase remained constant or decreased. Generally, mandibular intercanine width recordings were increased from pretreatment to final recording, indicating an overall permanent expansion. Dividing the sample into those who had bicuspids extracted and those who did not, produced "no discernible distinctive difference in the lower intercuspid distances."

He concluded, "Orthodontic movement and retention of teeth produce lasting changes only in those particular patients whose forces, including the anterior component of force, acting upon the teeth have changed in such a manner during treatment (and retention) as to support those particular teeth in the newly acquired positions." He further stated, "Orthodontic movement of teeth per se does not establish any tooth in its new position ultimately."

HERNANDEZ (1969) recorded the change of intercanine width during treatment and after a minimum of six months post-retention for twenty-five extraction and fifty eight non-extraction cases. He then related these to changes in

overbite.

He found that 100% of the extraction group had a net increase in intercanine width with a mean expansion of 1.9 mm. The reason given to explain this was "that most likely in these cases the canines were retracted into a wider part of the dental arch". In the non-extraction group 50% were expanded with a mean value of 1.0 mm. The amount of orthodonic movement required to produce these mean net values was not given. The relatively even distribution of the non-extraction group was interpreted as "a result of the planned treatment, where in some cases expansion is necessary and in some cases contraction is necessary for proper alignment of the teeth." The inference here is that if expansion is required, it can be obtained and maintained.

From the results of his study, 88% of extraction cases and 38% of non-extraction cases were initially overexpanded during treatment and relapsed to varying degrees to give a resultant permanent expansion. Therefore, although expansion was much more evident in the extraction cases, they were more likely to show relapse.

HERBERGER (1981) assessed 56 nonextraction cases at least 24 months out of retention. The sample was divided into groups that were retained with a 0.036 mm fixed lingual retainer to the first premolars for four, five, or six years.

The four year retention group maintained a average net increase in intercanine width of 1.4 mm from an initial expansion of 3.3 mm. For the five year group the average net increase was 1.0 mm of the 2.9 mm original expansion and for the six year group the net increase was zero from an original expansion of 1.9 mm. Of the 56 cases, 38 maintained a net

expansion postretention while 18 lost an average of 0.8 mm from their initial intercuspid width. During active treatment 92% of the sample were expanded; after the postretention period 68% still retained some of that added width. HERBERGER observed that "even though most cases showed some decrease from the immediate posttreatment width at final measuring, some of this could be attributed to settling, band space closure and, in some cases, slight lower anterior rotations. However, most of the cases did hold some of the expansion acquired during treatment."

The value of extended retention was assessed by comparing the cuspid to cuspid arch length loss for the five most severly relapsed cases in each group. In the four year group, the cuspid to cuspid was increased an average of 4.0 mm by treatment with a 2.0 mm net increase postretention. In the five year group, the increase in arch length was 3.5 mm and a net gain of 2.2 mm postretention. The six year group was increased an average of 6.5 mm and a net gain of 4.0 remained. HERGERGER noted, "it is significant that this was the group in which intercuspid width was increased the least, indicating that arch length increase was accomplished more by incisor advancement or buccal retraction than by increasing intercuspid width." He then concluded that "there is a need for varied and extended periods of retention due to the varied types and severity of problems inherent in each case treated." However, the six year group required greater initial increase in arch length for alignment than the other two groups. Therefore, with two variables, a definitive conclusion cannot be justified. That aside, the six year group suffered the greatest relapse (2.5 mm compared to 1.3mm

and 2.0 mm), which hardly substantiates his conclusion.

In conclusion he stated, "patients can be treated with cuspid expansion and a significant part of this expansion can be maintained in some cases."

7.1.2.Studies Critical Of Intercanine Expansion

PEAK (1956) compared the cuspid arch width at the beginning of treatment, at the time of retention, and six months or more out of retention. His sample was forty-three cases consisting of twenty-three Class I extraction cases, seven Class II extraction cases, and thirteen Class II non-extraction cases. Average expansion for the Class I extraction group was 2.43 mm. at the time of retention which relapsed to 1.62 mm. six months or more out of retention. The Class II extraction group showed similar figures of 2.37 mm. and 1.57 mm. respectively. For the entire extraction group the figures were 2.40 mm. and 1.59 mm. respectively. The Class II non-extraction group averaged 0.97 mm. at the time of retention and 0.71 mm. six months or more out of retention. From these results he concluded that "mandibular cuspid arch expansion in successful orthodontic treatment is limited." However he determined that the possibility of more expansion is indicated in the extraction group than the non-extraction group.

BISHARA, CHADHA, and POTTER (1973) investigated the stability of maxillary and mandibular intercanine width and the relapse experienced in overbite and overjet. Their sample consisted of thirty edgewise treated cases requiring the extraction of four first premolars.

They found that the mandibular intercanine width increased during treatment from a mean of 25.38 mm to 26.15 mm, or an increase of 0.77 mm. Postretention measurements revealed a mean intercanine width of 25.6 mm, a reduction of 0.55 mm from the posttreatment mean and an increase of 0.22 mm over the original mean. The mean percentage relapse was 71.4 %. They determined that "the most obvious conclusion from this investigation is that relapse in overbite, overjet, and intercnaine width is a reality."

SHAPIRO (1974) studied eighty orthodontically treated cases with pretreatment, end-of-treatment, and postretention models at least 10 years out of retention. The sample was divided into extraction and non-extraction cases of Angle's Class I, Class II division 1, and Class II division 2.

Mean increases in mandibular intercanine width were observed for all six groups during treatment, while mean decreases in this measurement were observed for all groups during the postretention period. Changes in intercanine width from pretreatment to postretention were more varied. The intercanine width decreased in Class I extraction cases and Class II division 1 extraction and non-extraction cases, whereas some degree of intercanine expansion was maintained in Class I non-extraction cases (0.3mm.) and in Class II division 2 non-extraction (0.1 mm.) and extraction (1.4 mm.) cases. This intercanine width expansion from pretreatment to postretention was found to be statistically significant on the basis of Angle class, with Class II division 2 cases demonstrating a greater ability to maintain intercanine expansion than the other two classes.

SHAPIRO concluded from this greater stability of intercanine

width expansion in Class II division 2 cases, along with a similar trend in arch length, that "In borderline extraction cases one might lean toward not extracting teeth in the mandibular arches of Class II division 2 cases while extracting teeth in similar arches of Class I and Class II division 1 cases." However, closer inspection of his results reveals that although overall, the Class II division 2 cases were expanded 2.4 mm. during treatment and relapsed 1.5 mm. postretention, for a mean net expansion of 1.0 mm., when analysed on an extraction/non-extraction basis a reversal of this result can be seen. That is, Class II division 2 extraction cases expanded 2.7 mm. during treatment and relapsed 1.3 mm. postretention for a mean net expansion of 1.4 mm. whereas, significantly, Class II division 2 non-extraction cases expanded 2.0 mm. during treatment and relapsed 2.0 mm. postretention for a mean net expansion of only 0.1 mm. which is actually less mean net expansion than the Class I non-extraction cases (0.3 mm.). This directly refutes his conclusion advocating a tendency not to extract in Class II division 2 cases and rather detracts from his statement, "An additional and perhaps more interesting finding of this study is that the Class II division 2 group of subjects demonstrated a significantly greater ability to maintain treatment expansion of intercanine width than did the Class I and Class II division 1 groups."

From his results, Class I and Class II division 1 extraction cases showed greater expansion during treatment and greater relapse postretention that the non-extraction cases. This trend was also evident when Angle's classification was disregarded.

GARDNER and CHACONAS (1976) studied the clinical records of 103 cases, 74 treated non-extraction and 29 were treated with the extraction of four first premolars. The records examined were pretreatment, posttreatment, and postretention models at least one year following the removal of all retention devices. Results were not differentiated for Angle's classification.

The canine width in non-extraction cases showed an increase during treatment of 1.23 mm. with a relapse of 0.72 mm. leaving a net increase of 0.52 mm., or a relapse of 58.5%. The canine width in extraction cases was increased during treatment by 1.92 mm. with a relapse of 1.13 mm. for a net expansion of 0.79 mm., or a relapse of 58.8%. 77% of nonextraction cases and 83% of extraction cases were expanded during treatment and relapsed 58.4% and 52.2% respectively.

They determined from examination of data representing all intercanine width dimensions that relapse amounts to 58% resulting in an effective net increase of 0.5 mm. which is not clinically significant. The effective net increase for expanded cases only was 0.8 mm. which is approaching clinical significance. In those cases where the objective was to expand, they observed two distinct groups: those cases where expansion was tolerated and those cases where it was not. They concluded that expansion of canines has a strong tendency to return to its original dimension independent of the type of treatment. The best guide for intercanine width is the original canine pretreatment width.

JOHNSON (1977) used a "limited sample size to test the concepts of canine and molar width and how they affected arch length." His sample of eleven cases were assessed at least

six years postretention and consisted of one Class III (non-extraction), seven Class II (four non-extraction), and three Class I cases (two non-extraction). Each case was individually analysed for cuspid width and arch length changes and overall comparisons were made for molar width, Bolton's analysis, and cephalometric analysis (Rocky Mountain Data Systems).

He found that the cuspid width in the entire sample from the start of treatment to postretention decreased on average 1 mm (range 1.5 mm increase to 1.5 mm decrease). Most of this reduction (0.95 mm, range 0 mm to -2 mm) occurred after the end of active treatment. From his results, relapse was slightly greater for extraction (-1.25 mm) than non-extraction cases (-1 mm). He concluded that the cuspid width is most likely to decrease after treatment (9 of 11) although on occasion a slight increase (2 of 11) was maintained.

EL-MANGOURY (1979) divided a sample of 50 "seemingly well treated orthodontic cases" into "stable" or "relapse" groups. Although this seems contradictory, intercanine width changes were recorded and found to relapse more in the "relapse" group (1.00 mm) than the "stable" group (0.42 mm). She concluded that, at the end of active treatment, the mandibular intercanine width should be maintained as originally presented. The statistical analysis performed on many variables revealed that mandibular intercanine width and the PP-GoGn angle are the two most important variables related to orthodontic relapse.

LITTLE, WALLEN and RIEDEL (1981) assessed at least 10 years postretention sixty-five cases previously treated with edgewise mechanics and first-premolar extractions. They found

that although a few cases showed a decrease in arch width during treatment, more than 60% showed canine expansion of more than 1mm. Sixty of the sixty-five cases showed canine constriction postretention, with most constricting more than 2 mm. No differences between Angle classes were noted in long-term stability of intercanine width. Class II division 2 cases did not show significant intercanine width expansion during treatment. However, there was a significant constriction of arch width during the postretention observation period. The general observation was that, with few exceptions, postretention reduction of intercanine width was a typical finding. However, many demonstrated a degree of net expansion over the original condition and a few even showed expansion of intercanine width during the postretention stage. Then, to cover all contingencies, they state that many cases had an intercanine width much less than the initial dimension. This "marked variation in response" was evident in all their comparisons for this study. Their final conclusion was that "arch dimensions of width and length typically decreased after retention whereas crowding increased. This occurred in spite of treatment maintenance of initial intercanine width, treatment expansion, or constriction."

UHDE, SADOWSKY and BEGOLE (1983) investigated 45 non-extraction and 27 extraction cases at least 12 years out of retention. They found that the mandibular arch intercuspid distance was increased during treatment and decreased posttreatment in all sample groups (Class I, Class II, non-extraction, and extraction) to or past the original intercuspid width. No statistically significant difference was found among the groups. Statistically significant

correlations were found between (1) cuspid and molar arch width decrease, (2) maxillary and mandibular arch width decrease, and (3) maxillary (not mandibular) arch width decrease and crowding.

They concluded that the intercuspid width dimension should not generally be violated and arch width increase was least tolerated in the cuspid region regardless of the original malocclusion or extraction therapy.

HO and KERR (1987) used a Reflex Metrograph to measure casts marked with a sharp pencil for a sample of 23 cases treated with four premolar extractions. They reported that the method error using this apparatus has been found to half that using callipers. Their results indicated that although the maxillary and mandibular intercanine widths are expanded during treatment, this is lost post-treatment in the mandibular arch while it was maintained in some cases in the maxillary arch. They recommended maintaining "original arch dimensions when finishing treated orthodontic cases."

7.1.3.Intercanine Width Summary

From the literature, evidence has been documented to support the contention that intercanine width can be expanded and maintained. WALTER (1953) originally came to this conclusion based on his results which were divided into cases which expanded during treatment and those in which arch width was reduced. For the "partial data" and "complete data" cases where intercanine width was expanded, the net expansion being 1.96 mm and 1.86 mm respectively. While this may be considered clinically significant for those cases that did

expand, his conclusion seems less convincing when considered in conjunction with the remaining cases where a net arch width reduction of 1.02 mm and 0.77 mm respectively was recorded.

The rationale for separating the results into cases that expanded and those that constricted was not given. It could be presumed that where expansion was achieved, it was intended. Similarly, if a net arch width reduction was recorded, this may have been a treatment objective e.g. in cases where canines are buccally displaced or bucally or distally tilted. However, these conditions were not stipulated and considering that the cases came from three different practices, it is difficult to imagine how they could be specified. Therefore, while such a distinction between treatment results reveals impressive mean net expansion values, it does not seem justified.

In order to make direct comparisons between the studies reviewed, average expansion and relapse values were calculated where possible from the results given. From these values, net expansion and percentage relapse were derived. These calculations along with the sample size (differentiating extraction from non-extraction) and the minimum duration defining postretention are presented in Table 3.

WALTER'S "complete data" sample (1953) had a mean net expansion of 0.59 mm which lends little support to his final conclusion. His later study (1962) revealed clinically significant relapse and inconclusive net expansion. Although he was less committed in his conclusions from the latter study, pointing out the "limitations in the present and previous reports", he still insisted that expansion was "obtained and maintained".

STEADMAN (1961) was more guarded his interpretation of the canine expansion he recorded, noting consideration must be given to the "anterior component of force", growth of bony, muscular and nervous tissues, and functional and emotional habits. HERMANDEZ (1969) also indicated that "more information concerning habits, tooth form, growth, maturation, and muscle balance" was needed.

HERBERGER (1981), however, had no reservations regarding expansion as a treatment modality despite the modest mean net expansion and significant relapse figures derived from his results. He was concerned with the retention period and attributed arch width relapse to "settling, band-space closure and other causes."

PEAK (1956) noted the limited potential of "mandibular cuspid arch expansion" but considered that more expansion was possible in the extraction than non-extraction group. However, the degree of relapse was also higher and perhaps clinically more significant. BISHARA et al (1973) described relapse as "a reality" and "inevitable", and were followed by SHAPIRO (1974), GARDNER and CHACONAS (1976), and LITTLE, WALLEN, and RIEDEL (1981) with similar comments regarding the stability of intercanine width expansion. JOHNSON (1977) stated that "cuspid width is most likely to decrease after treatment" and then conceded that "on occasion a slight increase was maintained." However the small sample (2 of 11) was inadequate and any conclusion seems inappropriate.

The percentage relapse figures given in Table 3 (p. 106) reveal a wide variation quantitatively and in interptretation. STEADMAN achieved similar figures to PEAK and yet they differed in their respective interpretations.

Similarly, WALTER and HERBERGER were at variance with BISHARA et al and GARDNER and CHACONAS. The largest percentage relapse was derived from SHAPIRO'S study, and despite his heterogeneous sample (i.e. Class I and Class II cases, and varied extraction regimes for the designated extraction cases) the reason for this disparity is not evident. However, the clinical significance is not as dramatic since the actual relapse value is more comparable with the other studies.

Results from the individual studies were tabulated to derive mean values for the largest possible sample and recorded under "TOTAL SAMPLE". Only the studies providing or deriving complete data for extraction and/or non-extraction cases were included. This calculation indicates that intercanine width was increased in both extraction and non-extraction cases and subsequently relapsed more in extraction cases, resulting in less net arch expansion. The only reliable exception to this was the study of UHDE et al, who found no significant difference between non-extraction and extraction intercanine relapse. The greater expansion in extraction cases has been attributed to the retraction of canines to a wider region of the arch. However, if this is the only or most significant factor, the resultant expansion should be maintained to a greater degree than non-extraction cases where, presumably, the canines are not significantly retracted. The results derived in Table 3 concur with those of SONDHI, CLEALL, and BEGOLE (1980) who found that the mesial or distal movement of canines does not to any great extent affect the stability of intercanine width. As in Table 3, they showed that where canines were moved distally during treatment (presumably extraction cases), greater relapse in the intercanine width

occurred in the posttreatment period. Therefore, two possibilities seem feasible. Either canines are not being retracted into a broader section of the arch, or the extraction of teeth alters the balance of forces between the dentition/occlusion, alveolar/basal bone, and the surrounding musculature. Thus the conditions may be established whereby the reduced alveolus around the extraction site provides inadequate support for the distalising canines, particularly in first premolar extraction cases, resulting in collapse in this region.

It is interesting to note that the mean expansion recorded by HO and KERR was less than other extraction samples, yet relapse was of a similar magnitude. This may indicate that, in spite of minimal expansion of intercanine width during treatment (as a treatment priority in their sample), postretention reduction of this dimension seems inevitable in extraction cases.

Significantly, all the studies reviewed concerned samples treated with the Edgewise appliance. No mention was made in any of the studies regarding the nature of the archwires used, preformed or otherwise, or the use of headgear and transpalatal arches. Very little data is available relating to the Begg technique. LEVIN (1977) assessed Begg technique treatment results and found that mandibular intercanine width decreased in the posttreatment period, irrespective of whether an increase or a decrease occurred during treatment. No significant net mean change was found and posttreatment changes in intercanine width were found to be related to changes in the anterior dental arch. No data was presented to permit direct comparison with other studies.

TABLE 3
RELATED STUDIES
INTERCANINE WIDTH CHANGES (mm)

AUTHOR YEAR	SAMPLE	POST-RET'N	CANINE INCR.	REL.	NET INCR.	REL. %
WALTER 1953	Non-exo 32 Extract 0	2½ yr —	NA —	NA —	0.59 —	NA —
STEADMAN 1961	Non-exo 15 Extract 7	1 yr 1 yr	1.86 2.63	-0.53 -0.57	1.33 2.43	28.5 21.7
WALTER 1962	Non-exo 50 Extract 50	2½ yr 3 yr	2.02 2.05	-1.16 -1.62	0.86 0.43	57.4 79.0
HERNANDEZ 1969	Non-exo 58 Extract 25	6 mth 6 mth	NA NA	NA NA	1.0 1.9	NA NA
HERBERGER 1981	Non-exo 56 Extract 0	2 yr —	2.76 —	-1.90 —	0.86 —	68.8 —
PEAK 1956	Non-exo 13 Extract 30	6 mth 6 mth	0.97 2.42	-0.26 -0.82	0.71 1.61	26.8 33.9
BISHARA et al 1973	Non-exo 0 Extract 30	— 6 mth	— 0.77	— -0.55	— 0.22	— 71.4
SHAPIRO 1974	Non-exo 22 Extract 58	10 yr 10 yr	0.7 1.7	-1.4 -1.9	-0.7 -0.3	200 112
GARDNER 1976 CHACONAS	Non-exo 74 Extract 29	1 yr 1 yr	1.23 1.92	-0.72 -1.13	0.51 0.79	58.5 58.9
JOHNSON 1977	Non-exo 6 Extract 4	6 yr 6 yr	NA NA	-1.13 -1.0	NA NA	NA NA
LITTLE et al 1981	Non-exo 0 Extract 65	— 10 yr	— 60% >1	— 92% >2	— NA	— NA
UHDE et al 1983	Non-exo 45 Extract 27	12 yr 12 yr	NA NA	-2.26 -2.13	NA NA	NA NA
HO & KERR 1987	Non-exo 0 Extract 23	—	— 0.57	— -0.93	— -0.36	— 163
TOTAL SAMPLE	Non-exo 230 Extract 204	6 mth 6 mth	1.75 1.69	-1.13 -1.28	0.62 0.39	64.6 75.7

7.2.INTERMOLAR WIDTH

7.2.1.Studies Advocating Arch Expansion

WALTER (1953) measured arch width changes in the first molar region using the same format and non-extraction sample as for the intercanine measurements. For "partial data" cases which remained expanded between the first molars after an ample period postretention, the mean value was 2.04 mm. Where the intermolar width was decreased, the mean value was 0.76 mm. For the "complete data" cases, the mean value where expansion was recorded was 1.96 mm, and for those cases where intermolar width decreased the mean value was 0.55 mm. As with the intercanine width recordings, only the "complete data" cases were compared with other studies in Tables 3 and 4 respectively. Thus methods were directly comparable and data from the "complete data" cases were not duplicated in the "partial data" cases. Intermolar width changes that occurred according to measurements taken pretreatment, posttreatment, and postretention (33 "complete data" cases) was summarised as

1. 3% expanded and remained stable.
2. 12% expanded during treatment and continued to expand during the postretention period.
3. 55% were expanded and tended to return toward their original position.
4. 12% were expanded and relapsed to their original position.
5. 9% were expanded and relapsed beyond their original position to record a net arch width reduction.

6. 3% constricted and remained so in that position.

7. 6% were constricted during treatment but relapsed toward their former position.

From these figures, 70% showed net intermolar expansion, 12% showed no net change, and 18% were constricted.

In his later study, WALTER (1962) found that of 50 non-extraction cases, 72% had an expanded intermolar width (mean 1.8 mm) and 26% constricted (mean 0.9 mm), with 1 case showing no change. For the same number of extraction cases, the reverse was evident. That is, 26% were expanded to an average 1.3 mm, while 70% were constricted an average 2.9 mm (4% no change).

STEADMAN (1961) showed a similar trend in his study. Of his sample of 31 where intermolar width changes were recorded, 64% of the non-extraction cases were expanded at the final recording, 36% showed no net change and none were constricted. Of the extraction cases, 50% were constricted and 50% showed no net change. From this he concluded that the extraction of bicuspids tends to decrease the lower intermolar widths. After analysing the movements of the molars from pretreatment to posttreatment to postretention, he further concluded that "regardless of what change is or is not made ... during the treatment period, the ultimate intermolar distance will be established according to the dictates of the balance of forces produced by the muscles, function, and growth of that particular individual.

7.2.2.Studies Critical of Arch Expansion

SHAPIRO (1974) found that the mean mandibular intermolar width increased during treatment in the three non-extraction groups (Class I, Class II div. 1, Class II div. 2) and decreased in the three extraction groups. Intermolar width decreased in all groups during the postretention period with the exception of the Class II div 2 non-extraction group, where it continued to increase slightly. Although the trend was to return to the pretreatment dimension during the postretention period in non-extraction cases, much of the treatment intermolar width expansion was maintained. A statistically significant difference between non-extraction and extraction groups was demonstrated, with the intermolar width maintaining much of its expansion in the nonextraction groups while decreasing in the extraction groups to a resultant width less than the original.

GARDNER and CHACONAS (1976) found that all 29 non-extraction cases of their sample of 103 were expanded in the molar region during treatment and noted the minimal amount of postretention relapse. The extraction cases were constricted and again a minimal postretention change (slight further constriction) was noted. They therefore concluded that the lower molar retains its width once positioned. They further stated, "In non-extraction cases it is apparent that molar width definitely can be expanded, and after the initial change or treatment change has taken place, the molar remains where it is regardless of the type of treatment."

JOHNSON (1977), found an overall treatment expansion (0.8 mm) of the intermolar width for his sample of 11. The

non-extraction cases expanded 0.3 mm during this period, while the extraction cases increased 1.8 mm. From the beginning of treatment to at least six years postretention, both groups showed a decrease of molar width. He concluded that "the molar width is apt to decrease from the beginning of treatment through the postretention period."

UHDE, SADOWSKY, and BEGOLE (1983) found that for their sample of 45 non-extraction and 27 extraction cases, the mean mandibular intermolar width decreased in the postretention period irrespective of the original malocclusion. Non-extraction cases maintained most of the increase gained during treatment, while extraction cases increased only slightly during treatment and decreased beyond the original intermolar width after treatment.

HO and KERR (1987) found that the mean intermolar width for 23 cases treated with premolar extractions was reduced during treatment followed by slight further constriction of this dimension following retention. The reduction during treatment was attributed to mesial movement of the molar during space closure.

7.2.3.Intermolar Width Summary

Results of intermolar width changes during and after treatment from the relevant studies have been converted where possible to permit direct comparison and presented in Table 4 (p. 112). The samples and tabulations were prepared according to the same criteria as Table 3.

WALTER (1953, 1962) and STEADMAN (1961), as mentioned previously, condoned to varying degrees, arch expansion as a

treatment objective and used their measurements of intermolar width changes along with those for intercanine width to substantiate their conclusions. It is interesting to note that STEADMAN'S extraction sample showed reduced intermolar width during treatment, (as did each of the other extraction samples except those of UHDE et al, who did not reveal the amount of treatment expansion they achieved), but subsequently relapsed in the postretention period toward the original dimension. Postretention change in the other extraction samples was a continued reduction in intermolar width. His sample in this instance was small (6) and may be subject to criticism.

SHAPIRO (1974) GARDNER and CHACONAS (1976), and JOHNSON (1977) while generally critical of arch width expansion during treatment, were somewhat less critical of molar expansion. SHAPIRO, referring to molar expansion, noted that "a large amount of treatment expansion was maintained" and GARDNER and CHACONAS recorded a net molar width increase that was "definitely clinically significant." They explained the molar expansion not as a primary treatment objective, but coincidental to distalising the lower molars into a wider portion of the arch by the use of "tip back" gable bends. Upper molars were distalised using headgear and similarly required expansion to accommodate the broader arch.

Posttreatment change in intermolar width was considerably less in non-extraction cases than extraction cases, with the exception of GARDNER and CHACONAS who recorded remarkably little change after active treatment for both groups.

The substantial continued decrease of intermolar width in extraction cases reported by WALTER (1962) and SHAPIRO (1974)

and for the overall sample during the postretention period may be explained by continued arch length reduction during this period, which has been reported by SHAPIRO and LITTLE, WALLEN and RIEDEL. Consistent with this explanation is the fact that GARDNER and CHACONAS reported very little continued reduction in molar width during the postretention period in extraction cases in conjunction with a correspondingly small reduction in arch length.

Contrary to the above-mentioned findings, SONDHI, CLEALL, and BEGOLE (1980) observed no apparent difference in the

TABLE 4
RELATED STUDIES
INTERMOLAR WIDTH CHANGES (mm)

AUTHOR YEAR	SAMPLE	POST-RET'N	MOLAR INCR.	REL.	NET INCR.	REL. %
WALTER 1953	Non-exo 33 Extract 0	2½ yr —	NA —	NA —	1.28 —	NA —
STEADMAN 1961	Non-exo 22 Extract 6	1 yr 1 yr	2.14 -2.00	-0.32 0.67	1.82 -1.33	15.0 34.0
WALTER 1962	Non-exo 50 Extract 50	2½ yr 3 yr	1.62 -0.64	-0.57 -1.00	1.04 -1.64	35.2 -156.3
SHAPIRO 1974	Non-exo 22 Extract 58	10 yr 10 yr	1.4 -1.0	-0.5 -1.1	1.0 -2.1	35.7 -110
GARDNER CHACONAS 197	Non-exo 74 Extract 29	1 yr 1 yr	2.04 -1.46	-0.06 -0.03	1.98 -1.49	2.9 -2.0
JOHNSON 1977	Non-exo 6 Extract 4	6 yr 6 yr	0.3 -1.8	decr. decr.	decr. decr.	NA NA
UHDE et al 1983	Non-exo 45 Extract 27	12 yr 12 yr	NA NA	-1.02 -1.26	NA NA	NA NA
HO & KERR 1987	Non-exp 0 Extract 23	— 3 mth	— -1.04	— -0.15	— -1.19	— -14.4
TOTAL SAMPLE	Non-exo 168 Extract 168	1 yr 1 yr	1.84 -1.01	-0.30 -0.70	1.54 -1.71	16.3 -69.3

stability of intermolar widths that were decreased in cases where the molars had moved mesially and those that were increased where molars had moved distally. They further concluded that mesial movement of the first molar in extraction cases bore no relationship to the amount of decrease in intermolar width.

7.3.THE SIGNIFICANCE OF ARCH WIDTH STABILITY

7.3.1.Anterior Alignment

A "cause and effect" relationship between mandibular intercanine width and mandibular incisor alignment has been implicated by several authors. This is exemplified in STEADMAN'S conclusion, "If the intermolar or intercuspid distances are made too great during treatment then the distances will decrease and this will cause crowding of the teeth. This crowding can be eliminated by keeping the intermolar and intercuspid distances to a minimum during the treatment." PUNEKY et al (1984) listed excessive intercanine expansion as an important consideration in contributing to the "irregularity of the mandibular incisors ... following orthodontic therapy."

FASTLICHT (1970) compared 28 treated cases with 28 untreated "neutroclusions" and correlations for a number variables were analysed. He found that the correlation of mandibular crowding with intercanine width in the treated group was "very significant". From this he determined that "where there was more intercanine width, there was more space and thus less crowding. It was observed that the cases with less intercanine

width were those which presented more crowding."

LOMBARDI (1972) found that from a sample of 30 extraction and non-extraction cases, the unstable or crowded cases showed a mandibular intercanine width increase of 1.9 mm during treatment, of which only 0.6 mm was retained. The stable cases were expanded only 0.3 mm and 0.1 mm was retained. From the correlation coefficients he concluded that "crowding occurred when the mandibular intercanine width was increased."

JOHNSON (1977), in assessing the effect of cuspid width on lower arch crowding, divided his sample into Group A (7 cases) with 1-2 mm of lower crowding at the end of treatment, and Group B (4 cases) with 2-4 mm crowding. Group A all decreased slightly in cuspid width from 0.5 mm to 1.5 mm. Two cases from Group B had no change in cuspid width and the other two had 2 mm reduction. From this he concluded, "These individual cases show that maintaining the cuspid width from the start of treatment through end of treatment may be an important factor in lower arch length stability." However, the results seem inconclusive and the sample too limited to derive any association.

Just as the results of FASTLICHT and LOMBARDO confirmed the earlier assertions of STEADMAN and PUNEKY, and verify the basic premise that stimulates investigation into arch width changes, it is not difficult to find contradictory evidence in the literature. LITTLE, WALLEN, and RIEDEL (1981) found that intercanine width change during treatment was a poor predictor of long-term crowding, with the degree of expansion or constriction having little association with postretention alignment. The change in postretention arch width was also poorly associated with final irregularity, and net change in

intercanine width showed no association with long-term alignment.

GILMORE and LITTLE (1984) in a similar study found only a weak association between incisor width and long-term incisor alignment. These two studies would appear to discredit two commonly implicated factors in anterior relapse. However, GILMORE and LITTLE qualified their results stating, "Many other factors are surely involved in the phenomenon of incisor crowding, and biologic variability may confound even the most careful study." This could equally apply to the results recorded by LITTLE, WALLEN, and RIEDEL. UHDE et al substantiated this when their analysis revealed that the nine variables they compared (including overjet, overbite, molar relation, canine and molar width changes, and arch crowding) accounted for only 41% of the variability of mandibular arch crowding. Of this 41%, intercuspid width relapse accounted for the most (12.5%).

7.3.2.Canine Disclusion

M^cCAULEY (1944) recognised the importance of the canine in both retention and function. He noted the tendency to place the lower canine so that it will occupy a position mesial to the upper when the maxillary and the mandibular teeth are in contact, but "the real need is to carry that mandible to a position (or carry the maxillary units to a position, as the case may be) so that the lower cuspid travels mesially to the upper cuspid when it is in its lateral excursion." He considered this to be "the key to functional arch form". In order to achieve this relation, it may be necessary to reshape

the cuspid, leave space between maxillary lateral incisor and cuspid, and possibly reshape the occlusal surfaces of the molars to adapt them to the cuspid occlusion. He summarised the rationale for this objective by stating, "the mandible, when released from its prison (retainer), will try to save the cuspids from the trauma of the severe interference experienced in lateral bite. It will seek an easier path. Obviously, this will be to the distal of the upper cuspid. Then, the mandible will start slipping, and soon you will be back where you started."

D'AMICO (1961) stated that the function of the upper canines is "more than a mechanical guidance of the mandible and mandibular teeth into centric occlusion." He considered canine function to be physiologically significant; "Shock contact of the upper cuspids by the opposing mandibular teeth during eccentric excursions causes transmission of periodontal proprioceptive impulses to the mesencephalic root of the fifth cranial nerve, which in turn alters the motor impulses transmitted to the musculature. This involuntary action lessens the tension of the musculature, thus reducing the magnitude of the forces being applied."

BEYRON (1964) in his study of Australian aboriginal occlusal relationships, noted the presence of "group function" during protrusive and lateral movements. Significantly, he noted the absence of occlusal contact on the non-working side. The shape and position of the canines and incisors did not prevent contact of the premolars and molars in gliding movements from lateral positions. He considered this contradictory to the concept of "cuspid protected occlusion", which postulates as normal or ideal the absence of contact between opposing

premolars and molars during gliding from a lateral position until the intercuspal position is approached.

RAMFJORD (1984) considered that to maintain neuromuscular harmony within the masticatory system, centric occlusion should be slightly in front of centric relation and in the same sagittal plane as the path made by the mandible in a straight protrusive movement from centric relation. Ideally, the distance between centric relation and centric occlusion is 0.2-0.5 mm. Freedom in centric consists of an unrestricted glide with contact maintained between centric relation and centric occlusion. He stated that there is no indication that cuspid-guided occlusion during eccentric movements is better functionally and electromyographically than group function. However, lateral functional guidance posterior to the cuspid "appears to be less ideal". He concluded, "Thus, ideal occlusion would be considered either group function with harmonious guidance on all of the teeth on the working side, or cuspid guidance. Protrusive excursions also should have smooth, unrestricted contact movement patterns with disocclusion of the posterior teeth a short distance from centric occlusion. Cuspid guidance in protrusive excursion also will give an optimal electromyographic response."

WILLIAMSON et al (1980) showed that the temporalis muscles are much more responsible than the masseter muscles for seating the condyles in centric relation when an anterior guidance appliance is used. Significantly, when the posterior teeth were in contact along with the anterior teeth, the masseter muscles showed much more activity. They interpreted this as validation of the concept of canines and anterior teeth discluding posterior teeth in eccentric movements; i.e.

if the posterior teeth are still in contact as the mandible is moved from centric relation, heavy muscle contractions of the pterygomasseteric sling can place undue lateral pressures on the periodontium of the posterior teeth. Conversely, the contention of the anterior teeth having to accept the heavy load instead of the posterior teeth when canine disclusion is present becomes negated. Since there seems to be minimal activity from the masseter muscles when there is no posterior contact there would be less force on the anterior teeth.

It is evident that intercanine width is important not only as a determining factor for space requirements of the lower incisors, i.e. esthetics. Significantly, the canines play an important role in maintaining the physiological harmony of the entire masticatory apparatus, i.e. function. If these two objectives are to be achieved and/or optimised through orthodontic treatment, it is evident that the lower canines must be placed in a stable position.

CHAPTER 8

MATERIALS AND METHODS

8.1.MATERIAL

The material for this study consisted of the mandibular plaster casts of 35 patients treated with the Begg appliance at the University Orthodontic Clinic, United Dental Hospital, Sydney. Three sets of models were taken for each patient at stages referred to as Stage A (prior to active treatemnt), Stage B (completion of active treatment) and Stage C (at least one year postretention).

8.2.SAMPLE

The 35 patients used in this study were selected according to the following criteria:-

1. Treatment with full Begg appliance.
2. Class I or Class II malocclusion.
3. Pretreatment and end-of-treatment casts available.
4. Treatment carried out by post-graduate orthodontic students at the University Orthodontic Clinic.
5. Cases treated non-extraction, first premolar extraction, or second premolar extraction; with extractions symmetrical, and completed prior to active treatment.
6. Permanent dentition cases with intact mandibular arches

except where extractions were carried out for orthodontic purposes.

Precluded from the sample were cases with any of the following conditions:-

5. Surgical cases.

6. Serial extractions.

7. Incomplete treatment, i.e. spaces not closed, excessive overjet or overbite at the end of treatment.

Approximately 300 cases were reviewed and, after initial assessment according to the criteria listed above, 175 patients were contacted for final records (stage C models). From the 70 patients who responded to these recalls, 35 were finally deemed suitable. This sample consisted of seven first premolar extraction cases (2 male, 5 female), sixteen second premolar extraction cases (2 male, 14 female) and twelve non-extraction cases (5 male, 7 female). The average age for the sample was 13 years 11 months and average treatment time 21 months. The limited sample size reflects the intention to comply strictly with selection criteria, although the most limiting factor was the availability of complete records. The small number of first premolar extraction cases may be an indication of the decreasing incidence of this treatment for the mandibular arch.

8.3.MEASUREMENT

8.3.1.Landmarks

Intercanine width was measured at two points (Fig. 1): (1) The cusp tip measurement was recorded from the mid-point of the "central-labial lobe" of each canine, as described by WALTER (1953). Where excessive wear was evident and the cusp tip was not a well defined landmark, a point was identified on the incisal surface coincident with the intersection at the mid-point of the mesio-distal and bucco-lingual planes.
(2) The buccal surface landmark was determined by the intersection of a "vertical" line drawn in the midline, parallel with the long axis of the canine, with a "horizontal" line on the buccal surface, perpendicular to the long axis of the canine, and 5 mm from the incisal edge. A bracket positioning gauge (Ormco Pty Limited) with a finely sharpened lead point was used to draw the "horizontal" line.

It was decided to measure intermolar width from the mesio-lingual cusp of the first permanent molar (Fig. 1), rather than the mesio-buccal cusp, as greater occlusal wear and poorer cusp definition was associated with the latter. Accordingly, intermolar width was defined from the mid-point of the mesio-lingual cusp tip.

Cusp tip landmarks were "spotted" with a finely sharpened soft (2B) lead pencil which was found to mark a fine, distinct point with minimal pressure, and was easily erased if incorrectly positioned. After landmarks were identified and marked on each stage model, the points were compared and repositioned, if necessary, to maximise consistency.

8.3.2.Measuring Instrument

All measurements recorded during this study were made using hardened stainless steel 160 mm Dual Callipers (Helios) with a 2 mm dial gauge callibrated to 0.02 mm (Fig 2). The external measurement jaws were machined to a fine point from triangular cross-section support to facilitate accurate, reproducible location of landmarks.

8.3.3.Experiment

The procedure observed for recording arch widths for each case is summarised as follows:-

1. The six landmarks on each of the three stage models were identified and marked as described above.
2. Corresponding landmarks were compared between stage models, and repositioned as required.
3. Measurements were recorded sequentially, beginning with intercanine width (cusp tip), followed by intermolar width and intercanine width (buccal surface) for each stage model, beginning with the pretreatment model, followed by the end of treatment and postretention models.
4. Step 3 was repeated twice, resulting in three replications for each dimension; a total of 945 measurements. Measurements were recorded in the sequence described to minimise operator bias for individual measurements.

FIGURE 1
MEASUREMENT LANDMARKS
Intercanine Width (Buccal Surface) Landmark
Intercanine Width (Cusp Tip)
Intermolar Width

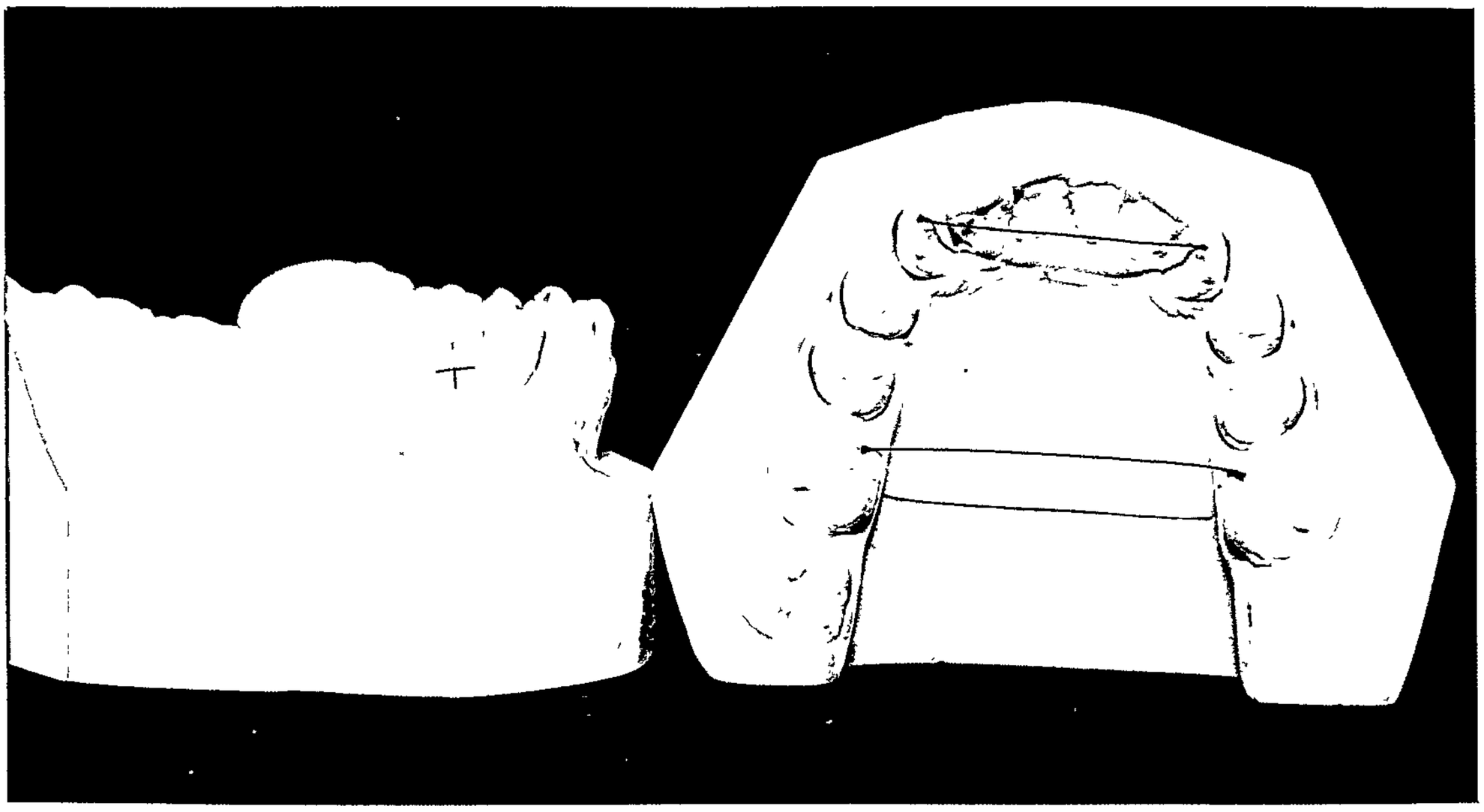
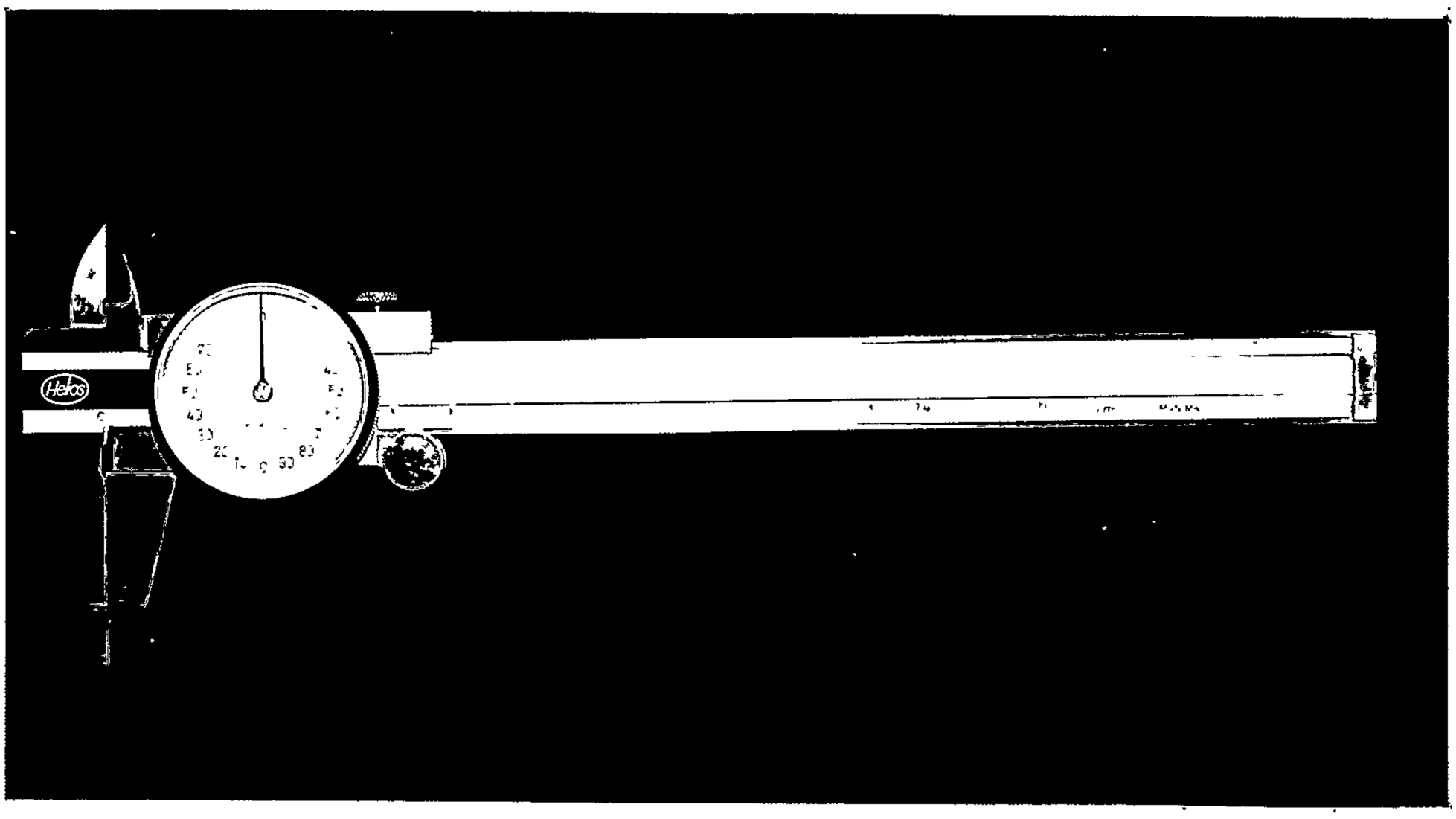


FIGURE 2
MEASURING INSTRUMENT
Helios 160 mm Dual Callipers



8.4.STATISTICAL ANALYSIS

8.4.1.Replications

The three replications for each dimension were averaged to give the values for the three dimensions recorded for each case at each stage for the three treatments investigated (see Tables 11, 12, 13). The range for replications for intercanine width (cusp tip) and intermolar width was ≤0.06 mm (except one case, range = 0.08 mm). The range for replications for intercanine width (buccal surface) was ≤0.10 mm (except one case, range = 0.12 mm). These values are an indication that (1) measurements from the occlusal surface are easier to define and measure, and (2) landmarks constructed on the buccal surface are more difficult to compare for consistency, and also to reproduce between replications if the lead pencil marking is disturbed.

8.4.2.Analyses

Two groups of analyses were performed with the data.

(1) Analyses of Variance:- Arch Widths At Stages.

The purpose of these analyses (see Tables 5, 6, and 7) was to determine the significance of differences between arch widths at each stage for different treatments. From the individual means derived from replications as described above, mean values were calculated for intercanine width (cusp tip), intercanine width (buccal surface), and intermolar width within stages (A=pretreatment, B=end of treatment, C=postretention) and treatments (first premolar extraction,

second premolar extraction, and non-extraction). Prior to analysis of variance of this data, outlyers were identified using "Minitab" program, and eliminated from the original sample. By doing so, a more homogenous sample is identified that will not be disproportionately influenced by excessively large or small dimensions. While this would not influence mean values in a large sample, the results from a limited sample, as in this study, would be adversely affected. The resultant "clean" data was then analysed using "Genstat" statistical program.

(2) Analyses Of Variance:- Arch Width Changes During Periods

The purpose of these analyses (see Tables 8, 9) was to determine the significance of changes in arch widths during periods (treatment period = B-A, postretention period = C-B, net change = C-A) for each treatment. The criteria for eliminating unsuitable cases from the original sample for these analyses vary from the previous analyses since cases that were expanded or constricted prior to treatment may have changed during periods in a similar pattern to the remainder of the sample. This can be verified or refuted by comparison with the previous analyses. Accordingly, the cases eliminated from these analyses were those with anterior spacing where constriction of intercanine width occurred during treatment and if included in the analysis, would disproportionately influence the results due to the vector of the change recorded. The resultant "clean" data was analysed using "Systat" statistical program.

The data were also analysed to compare changes between intercanine and intermolar widths by periods within treatments (see Table 10).

CHAPTER 9

RESULTS AND DISCUSSION

9.1.MANDIBULAR ARCH WIDTH AT STAGES

The total sample (Tables 11, 12, 13) was analysed to eliminate outlyers prior to analyses of variance of mandibular arch widths at stages (A, B, C - as described previously). This was done on the basis that excessively large or small individual values would disproportionately influence the resultant mean values. In Figures 3 to 13, presented in this chapter, numbers down the X-axis indicate arch width while stages are indicated along the Y-axis or within the figure. Representations of axial inclination (Figs. 5 - 10) are generated by a line joining a point representing the cusp tip and a point representing the buccal surface (B.S.).

9.1.1.INTERCANINE WIDTH - CUSP TIP

9.1.1.1.Results

The mean values for intercanine width measured at the cusp tip and analysis of variance are presented in Table 5. Mean values for first premolar, second premolar, and non-extraction treatments at each stage are recorded in columns, followed by the mean values for stages over all treatments. Mean values for each treatment at pre-treatment (stage A) are recorded in row A, end of treatment (stage B) in row B, and post-retention

in row C (stage C), followed by the means for treatments over all stages. Comparison of mean values using Least Significant Differences showed that means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level, e.g. the mean intercanine width for first premolar extraction cases at stage A is significantly different compared to that for second premolar extraction cases (as indicated by dissimilar superscripts: b, a respectively), but not significantly different compared to the mean intercanine width at stage B (as indicated by similar subscripts: a, a). By convention, the lowest value in a row or column being compared is assigned "a" superscript or subscript respectively, followed, if significantly different, by "b" and "c" in ascending magnitude. In particular cases, statistical significance has been indicated in the text.

Main Effects

(1) **Stages:** Analysis of variance (see Table 5) showed that means of stages over all treatments are not statistically different.

(2) **Treatments:** Similarly, there are no significant differences between the means of treatments over all stages.

Interaction

The variance ratio for interaction between treatments and stages is 1.734, and although not significant at the 5% level, indicates a probability of $0.1<P<0.2$. This was considered to be worthy of further analysis.

(1) **Stages Within Treatments:** This revealed significant

differences for the second premolar treatment between stages A and B (P=0.033), and stages B and C. There was no significant difference between stages for first premolar or non-extraction treatments.

(2) Treatments Within Stages: A difference approaching significance at the 5% level (P=0.063) was evident between intercanine widths for first and second premolar extraction treatments at the beginning of treatment (stage A). This was considered sufficiently significant to be assigned dissimilar superscripts. No significanct differences between treatments were evident at stages B or C.

TABLE 5
INTERCANINE WIDTH - CUSP TIP

(A) MEANS WITHIN TREATMENTS AND STAGES

STAGES	TREATMENTS			
	1st PM	2nd PM	NON-EXT	TOTAL
A (N)	26.00^{b}_{a} 5	24.95^{a}_{a} 11	25.46^{ab}_{a} 11	25.35 27
B (N)	25.94^{a}_{a} 5	25.98^{a}_{b} 9	25.43^{a}_{a} 9	25.76 23
C (N)	25.14^{a}_{a} 5	25.10^{a}_{a} 10	25.86^{a}_{a} 10	25.42 25
TOTAL (N)	25.68 15	25.31 30	25.59 30	25.50 75

Means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level.

(B) ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MS	VR	P
STAGES	2	1.143	1.107	NS
TREATMENTS	2	0.887	0.860	NS
STAGES.TREATMENTS	4	1.791	1.734	0.153
RESIDUAL	66	1.032		
TOTAL	74	1.072		

9.1.1.2.Discussion

Main Effects

(1) Stages: Although not statistically significant at the 5% level, there was a tendency for slight expansion of intercanine width at the cusp tip during treatment followed by relapse during the postretention period.

(2) Treatments: No significant differences.

Interaction

Interpretation of the significance of the difference between means discussed below should be qualified by the observation that Mean Square for interaction only approached significance at the 10% level (P=0.153).

(1) Stages Within Treatments: Intercanine width was expanded during treatment for second premolar extraction treatments (Fig. 3). This may be explained according to diagnostic criteria. Second premolar extraction cases are generally those where minimal retraction of the anterior segment is indicated due to profile considerations, i.e. where incisors are to be uprighted without retraction, or maintained in a slightly proclined position to compensate a Class II skeletal base, or where mesial movement of the molar is required to correct a Class II molar relationship. In such cases, intercanine width must be expanded (with or without further anterior proclination) to facilitate unravelling of crowding. This expansion was found to relapse almost entirely. The contention that intercanine width expansion in these cases is associated with unravelling of crowding may be substantiated by the absence of expansion in non-extraction

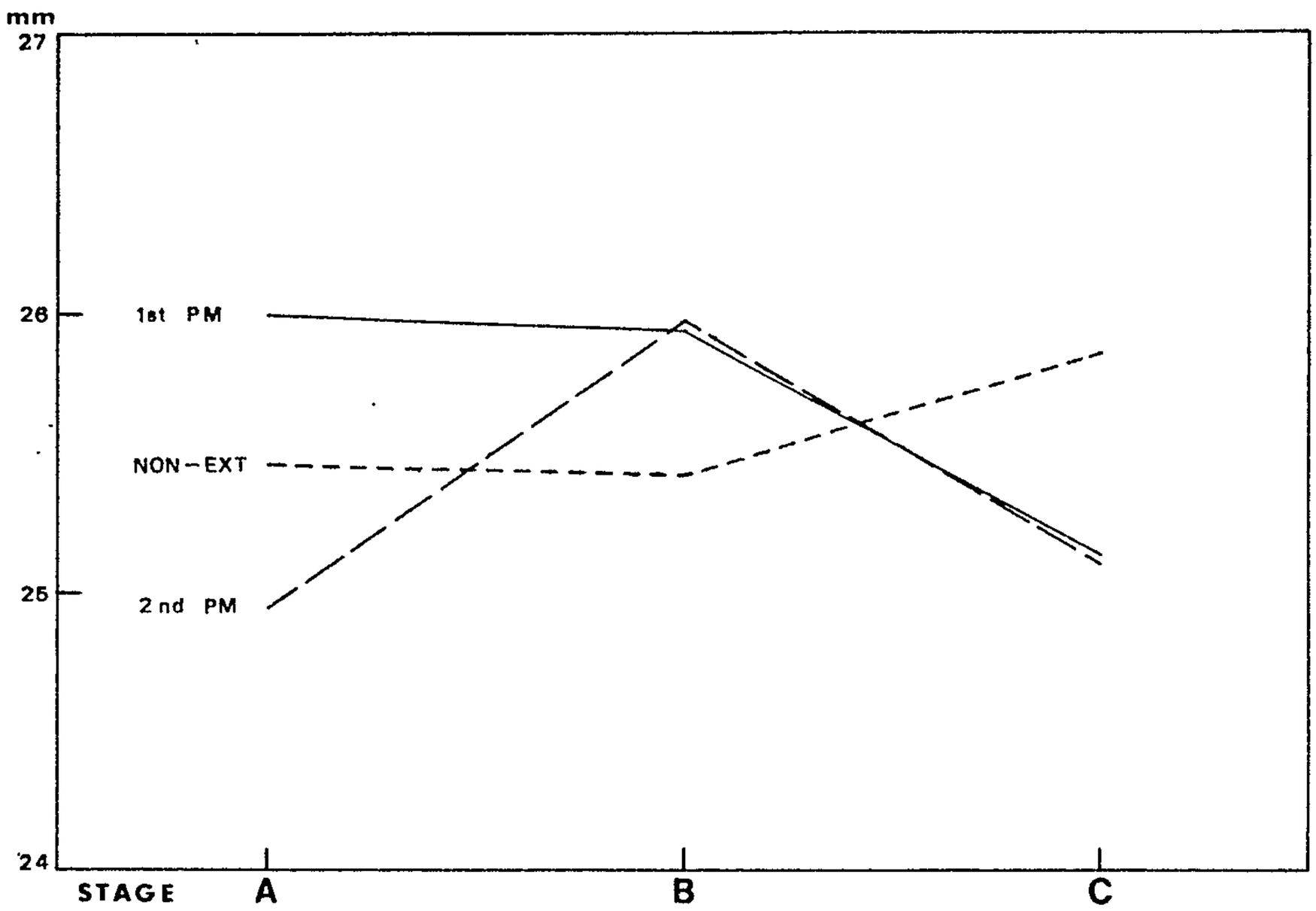
treatments where presumably minimal crowding exists.

(2) Treatments Within Stages: It would seem that the pretreatment intercanine width for first premolar extraction treatments is larger than that of second premolar extraction treatments (Fig 3). Once again, this may reflect the diagnostic criteria for first premolar extraction, i.e. crowding and/or proclination of the anterior segment with the canines migrated or erupted anterior to their normal position in the arch with associated labial/buccal tipping. HO and KERR (1987) make a similar observation regarding mandibular canine retraction in their premolar extraction sample (first and second premolar extraction cases weren't differentiated). They stated, "The fact that only a small amount of expansion was obtained during treatment is explained by the buccal displacement of many canines prior to treatment which when moved distally are not expanded to any significant degree."

Trends

It is interesting to note that the intercanine width of both non-extraction and first premolar extraction cases is not expanded during treatment (Fig. 3), yet this dimension tended to increase marginally during the post-retention period in non-extraction cases whereas first premolar cases tended to decrease (P=0.184). Two inferences may be derived from this observation: (1) Canine retraction in first premolar extraction cases may result in the canines being held in a more expanded position than that determined by the stabilising influences of arch form. (2) Remodeling and reorganisation in the extraction site may alter the balance and expression of the stabilising influences of arch form.

FIGURE 3
INTERCANINE WIDTH - CUSP TIP



9.1.2.INTERCANINE WIDTH - BUCCAL SURFACE

9.1.2.1.Results

The mean values and analysis of variance for intercanine width measured at the buccal surface are presented in Table 6.

Main Effects

(1) **Stages:** Analysis of variance showed that means of stages over all treatments were significantly different (P=0.003, see Table 6).

Stages Within Treatments: No significant Mean Square for differences between stages were found for first premolar extraction cases. Second premolar extraction treatments revealed a significant difference at stages B and C compared

to stage A. Non-extraction cases revealed a significant difference between Stage A and Stage C, with Stage B not significantly different from either at the 5% level.

(2) Treatments: Difference between the means of treatments over all stages approached significance at the 10% level (P=0.110, see Table 6).

Treatments Within Stages: No significant differences were found between means of treatments at Stage A or Stage C. At Stage B, means for second premolar extraction and non-extraction treatments were significantly different.

Interaction

There was no interaction between stages and treatments.

TABLE 6
INTERCANINE WIDTH - BUCCAL SURFACE

(A) MEANS WITHIN TREATMENTS AND STAGES

STAGES	TREATMENTS			
	1st PM	2nd PM	NON-EXT	TOTAL
A (N)	29.35^{a}_{a} 5	28.80^{a}_{a} 8	28.67^{a}_{a} 9	28.87 22
B (N)	29.96^{ab}_{a} 5	30.30^{b}_{b} 9	29.18^{a}_{ab} 10	29.76 24
C (N)	29.31^{a}_{a} 5	29.71^{a}_{b} 8	29.56^{a}_{b} 10	29.56 23
TOTAL (N)	29.55 15	29.63 25	29.15 29	29.41 69

Means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level.

(B) ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MS	VR	P
STAGES	2	4.8855	6.343	0.003
TREATMENTS	2	1.7616	2.287	0.110
STAGES.TREATMENTS	4	1.1740	1.524	0.207
RESIDUAL	60	0.7702		
TOTAL	68	0.9442		

9.1.2.2.Discussion

Measurement of intercanine width at the buccal surface, when interpreted in conjunction with the cusp tip values, relates axial movements of the canine rather than simply demonstrating transverse movements as indicated by each measurement individually.

Main Effects

(1) Stages: Mean values for intercanine width measured at the buccal surface for stages over all treatments was found to increase during treatment and maintain most of that expansion during the postretention period.

Stages Within Treatments: Although not statistically significant, the buccal surface width for first premolar extraction cases appeared to be expanded slightly during treatment (Fig. 4). Since the cusp tip width was not expanded during treatment, there was a tendency for the canine root to move buccally, and therefore the canine becomes inclined more lingually (Fig. 5). As the cusp tip width was not expanded as it was retracted into a broader section of the arch during treatment, as would be expected, it may be that the canines were originally expanded at the cusp tip, and hence the more lingual inclination of the canines during treatment is, in effect, an uprighting movement. This was followed by a bodily reduction in intercanine width during the postretention period.

FIGURE 4
INTERCANINE WIDTH - BUCCAL SURFACE

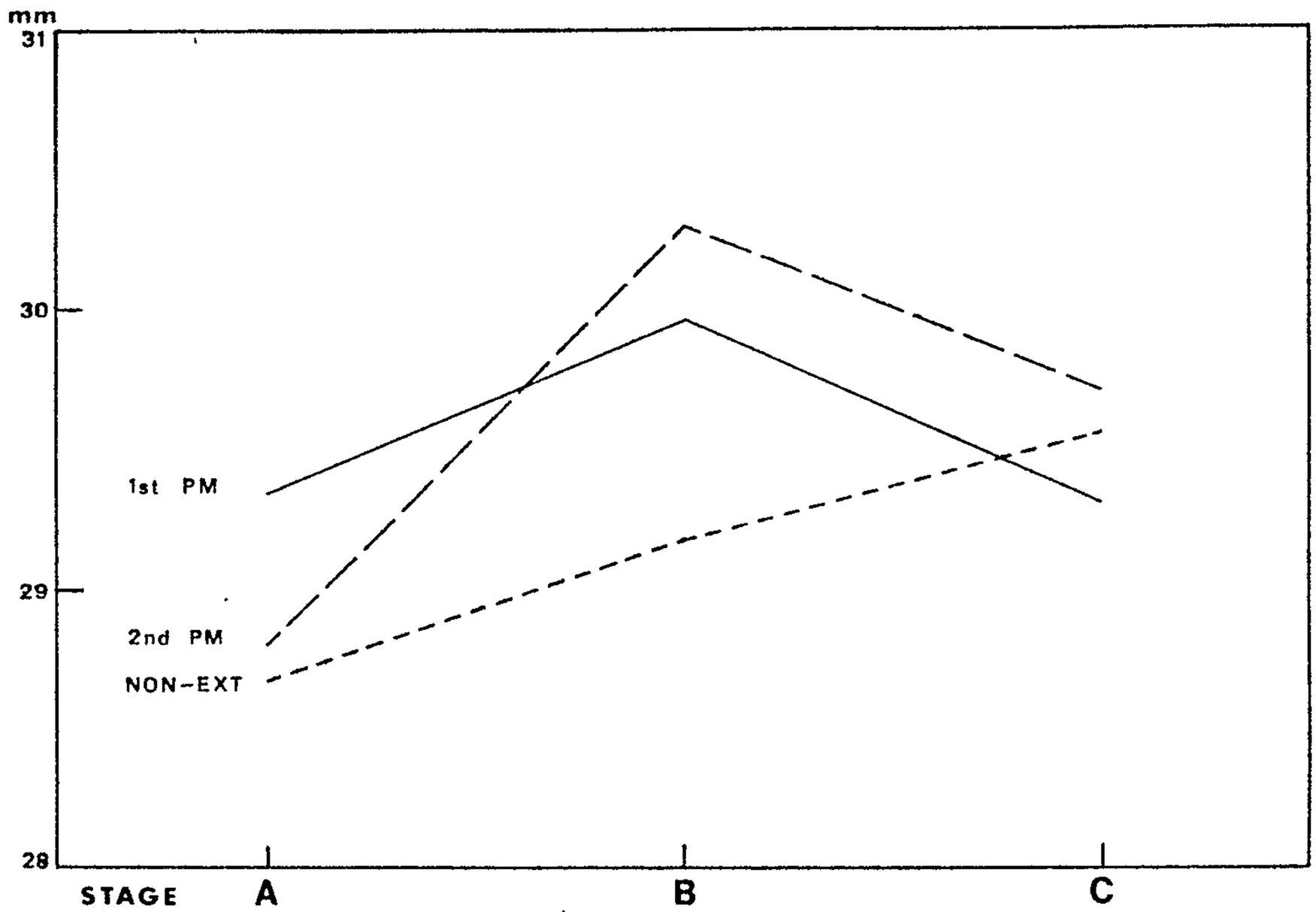
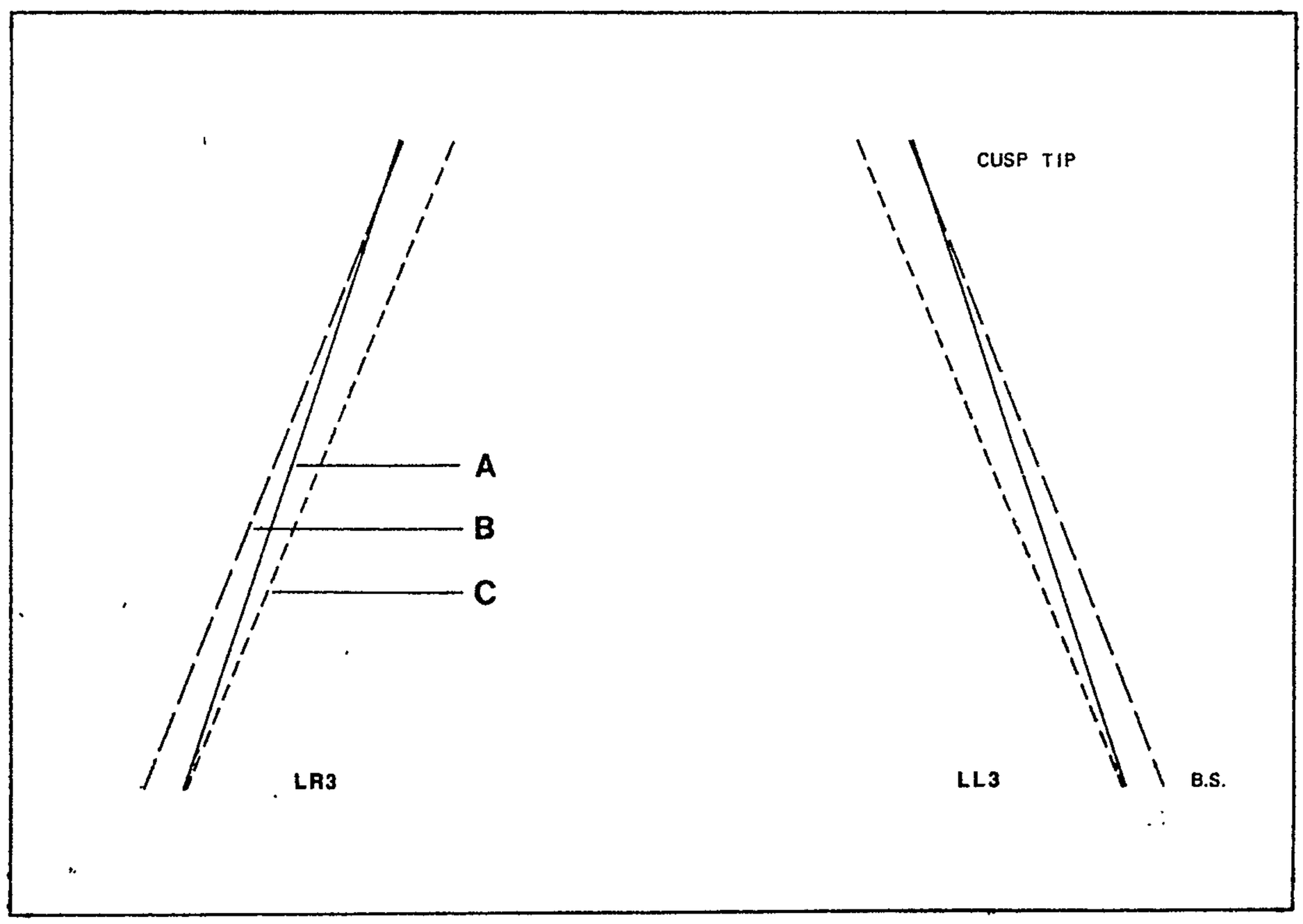


FIGURE 5
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION
FIRST PREMOLAR EXTRACTION TREATMENT WITHIN STAGES



In second premolar extraction cases, there was significant expansion at both the cusp tip and buccal surface during treatment (Fig. 6), indicating bodily expansion during this period. During the postretention period, significant relapse at the cusp tip accompanied by a tendency toward buccal surface relapse, resulted in intercanine width relapse due to a combination of lingual tipping and bodily movement during this period. Distances indicated |—s—| are significantly different at the 5% level.

Non-extraction cases, although not expanded at the cusp tip during treatment, tended toward expansion at the buccal surface (Fig. 7). This movement may result in the slight expansion of the cusp tip observed during the postretention period, aided by continued buccal surface expansion.

FIGURE 6
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION
SECOND PREMOLAR EXTRACTION TREATMENT WITHIN STAGES

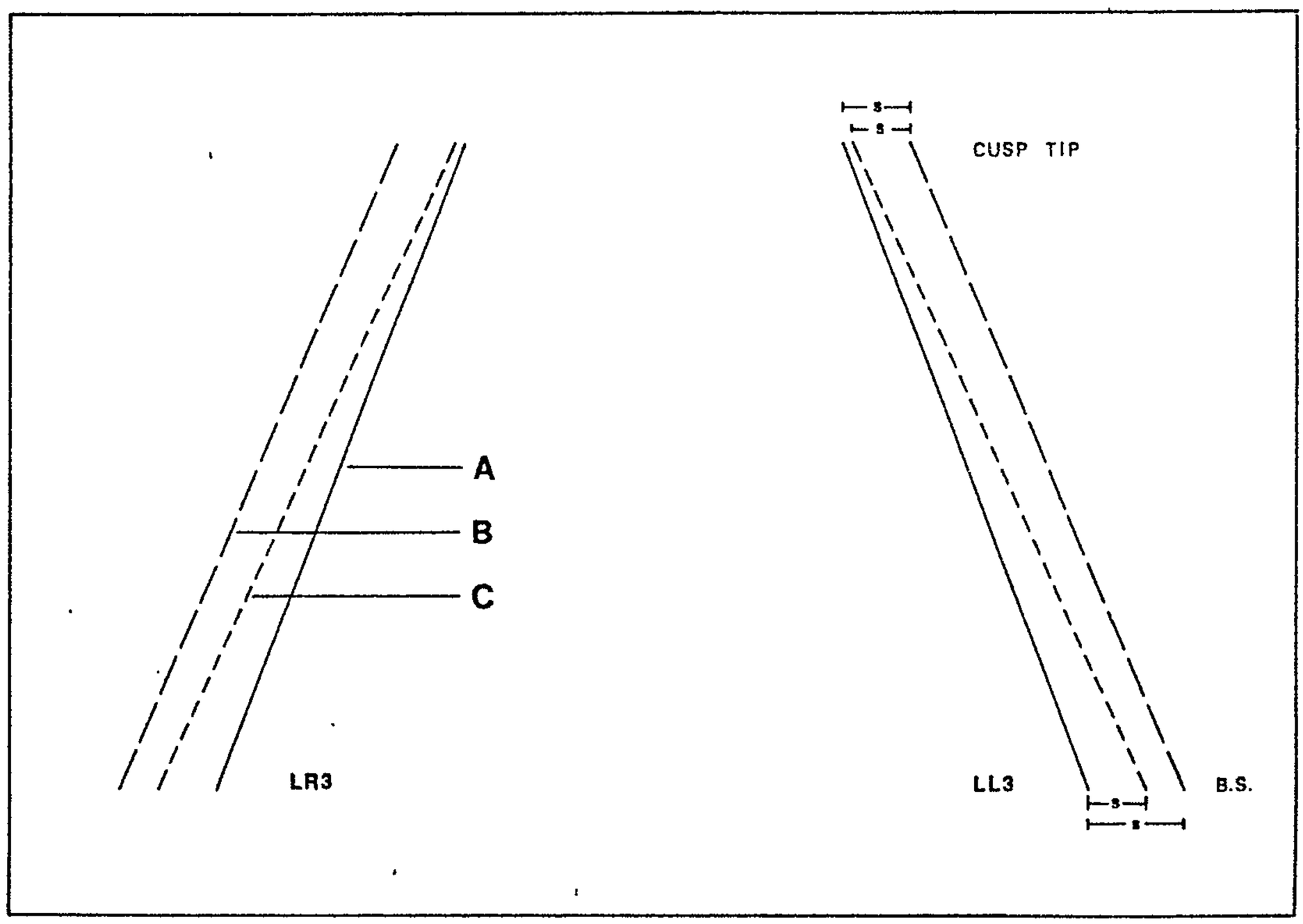
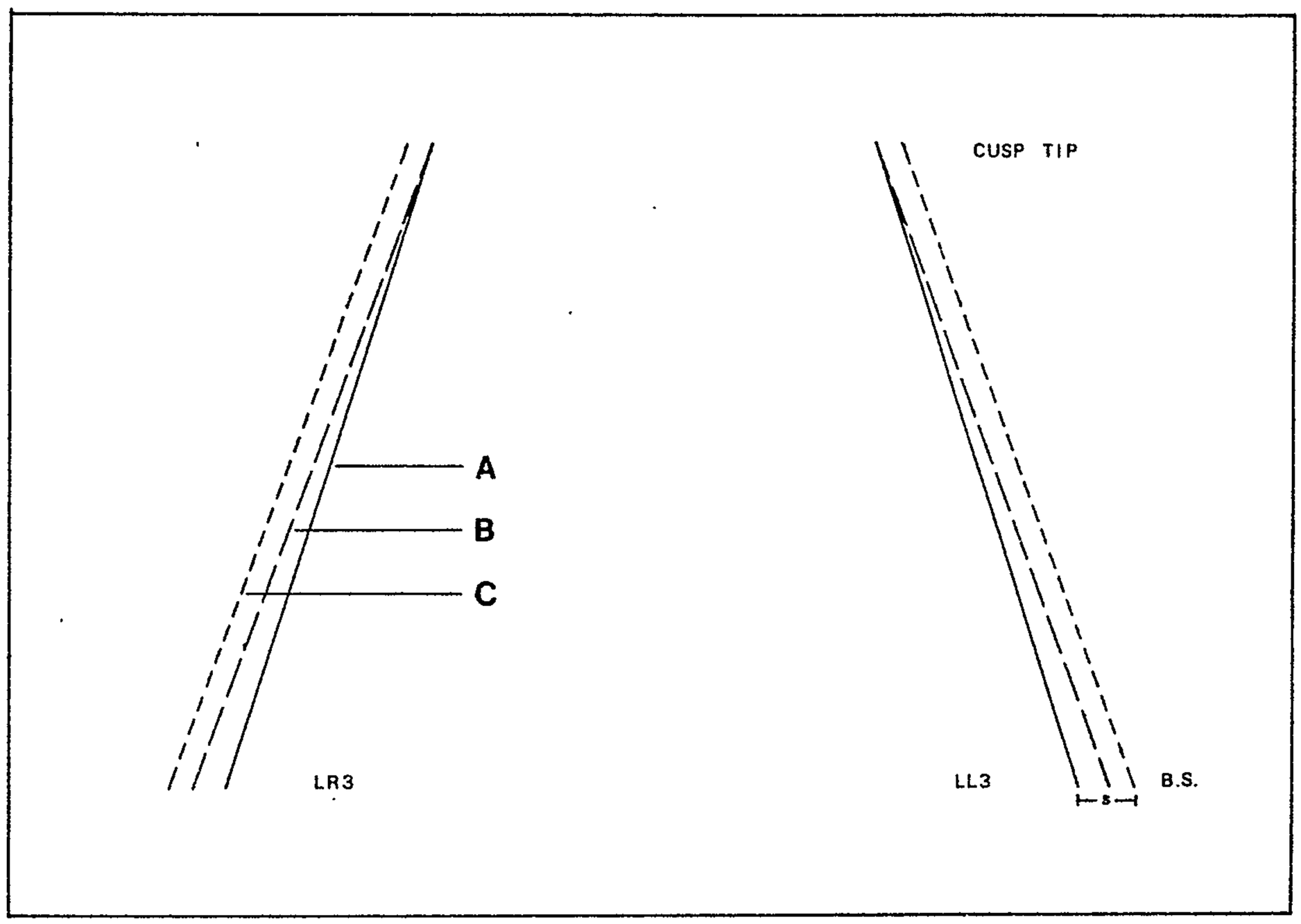


FIGURE 7
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION NON-EXTRACTION TREATMENT WITHIN STAGES



(2) **Treatments:** The effects of treatments may be interpreted by discussing differences between means of stages.

Treatments Within Stages: No significant difference for mean intercanine width measured at the buccal surface was found between treatments at the start of treatment. Since the same dimension measured at the cusp tip was greater for first premolar extraction cases than second premolar extraction cases, it is confirmed that the canines of first premolar extraction cases are buccally tipped compared to canines of second premolar extraction cases (Fig. 8). Once again, this may reflect diagnostic criteria for extracting first premolars.

Although not statistically significant, there may be a

tendency for second premolar extraction cases to have a greater intercanine width measured at the buccal surface at the end of treatment than first premolar and non-extraction cases (Fig. 4). This again may reflect the greater expansion required to alleviate crowding in second premolar extraction cases since the canines are not retracted, as discussed previously.

The axial inclinations of mandibular canines at the end of treatment and postretention (stages B and C) are illustrated in Figures 9 and 10 respectively. It is interesting to note the relationship of non-extraction canines compared to first and second premolar extraction canines at these stages.

FIGURE 8
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION PRETREATMENT (STAGE A) WITHIN TREATMENTS

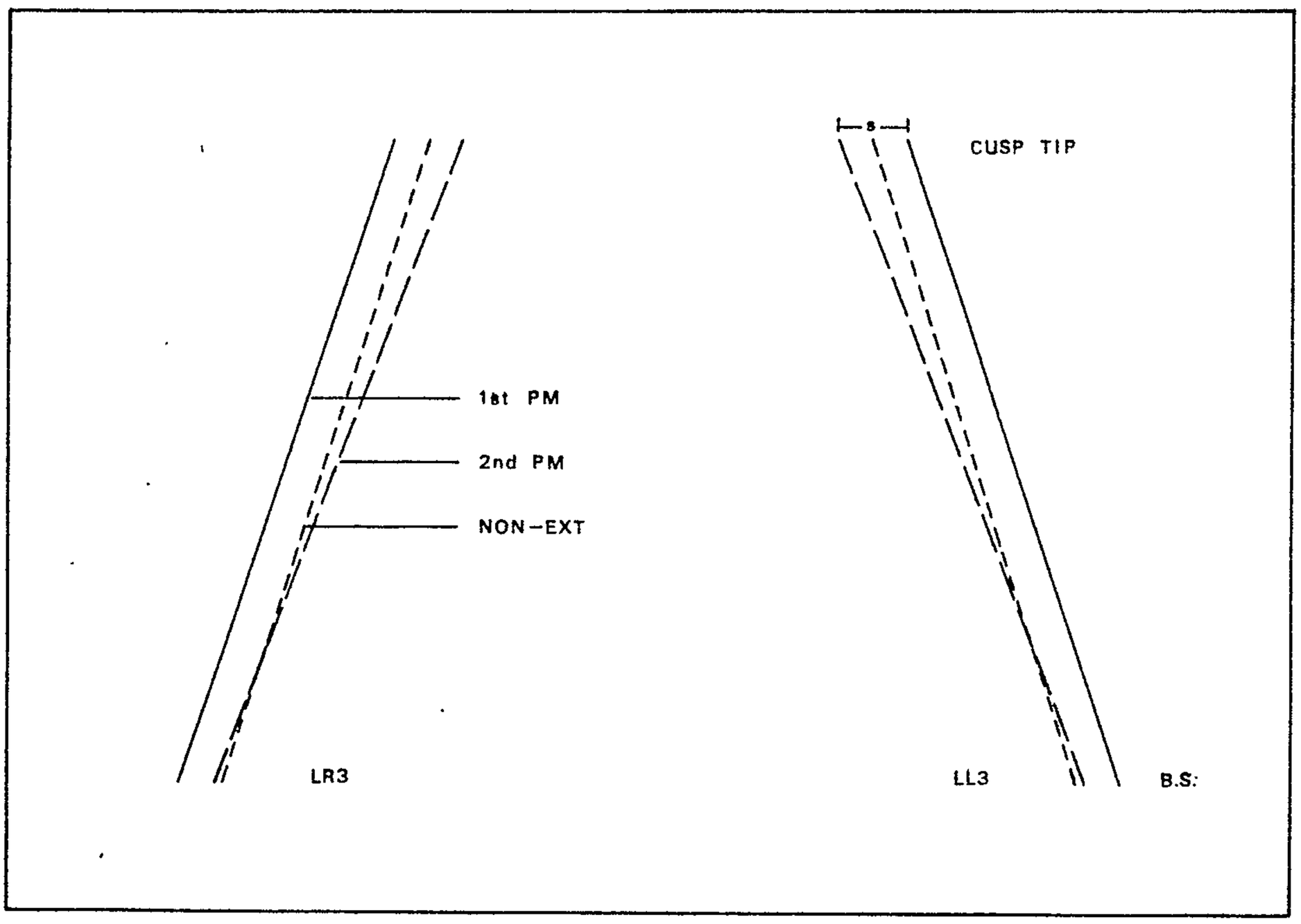


FIGURE 9
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION
POST-TREATMENT (STAGE B) WITHIN TREATMENTS

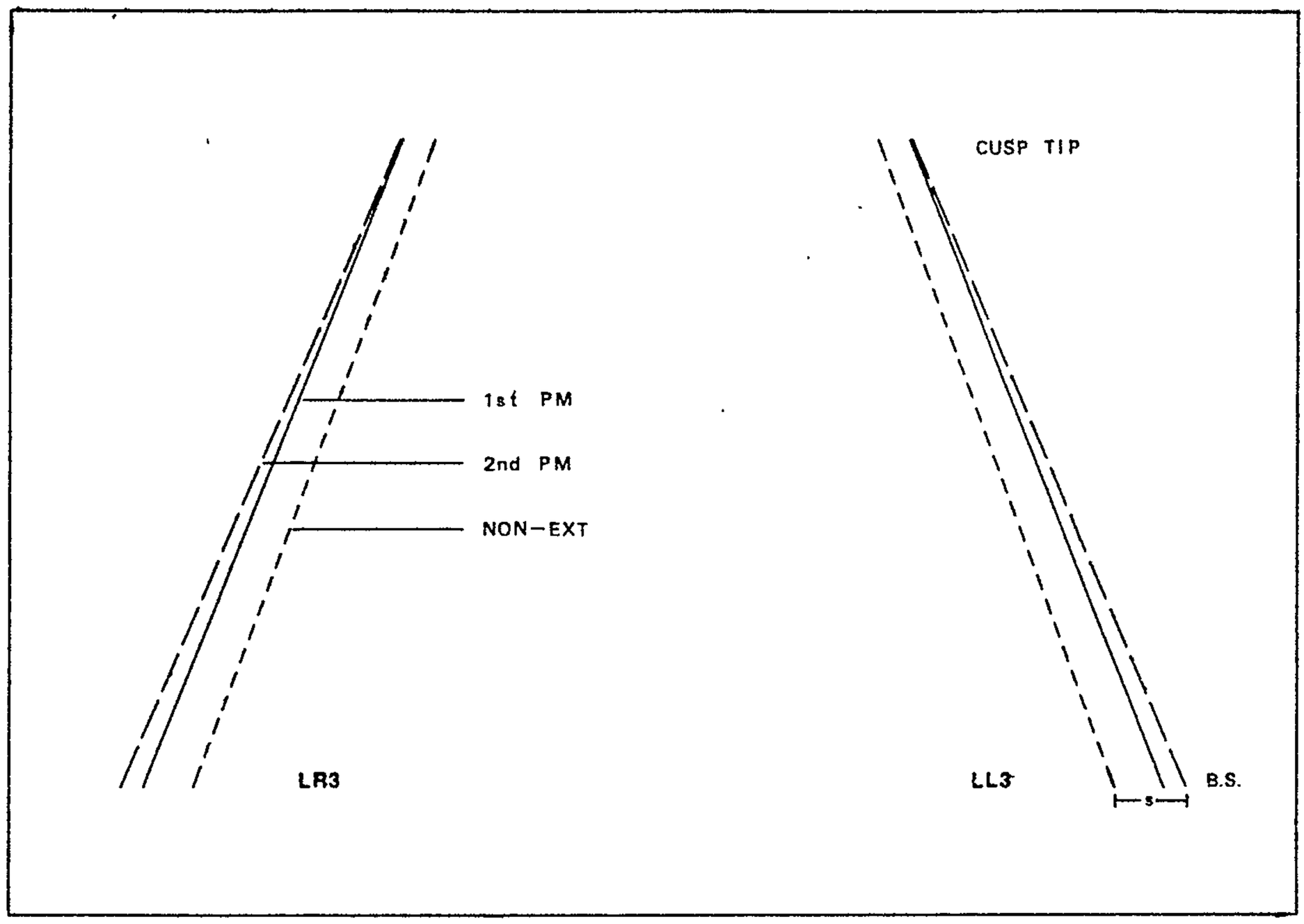
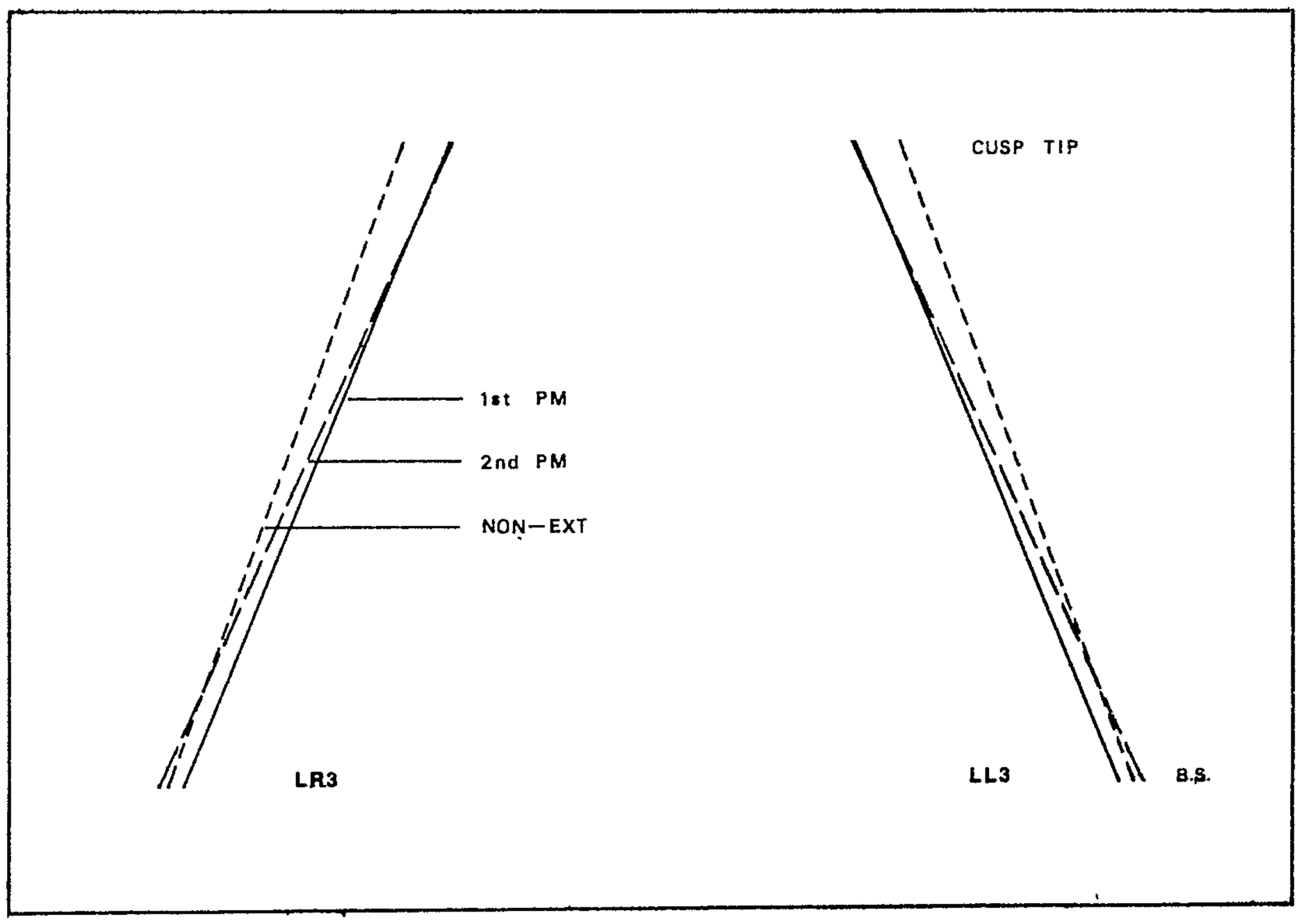


FIGURE 10
REPRESENTATION OF MANDIBULAR CANINE AXIAL INCLINATION
POSTRETENTION (STAGE C) WITHIN TREATMENTS



9.1.3.INTERMOLAR WIDTH

9.1.3.1.Results

The mean values for intermolar width measured at the mesio-lingual cusp tip are presented in Table 7.

Main Effects

(1) **Stages:** The mean values of intermolar width for stages over all treatments were found to be significantly different (P=0.001)

Stages Within Treatments: No significant differences between stages for intermolar widths were found within the first premolar extraction group and the non-extraction group. In the second premolar extraction group, stage A was significantly different from stages B and C.

(2) **Treatments:** The mean values of intermolar width for treatments over all stages were found to be highly significanly different (P<0.001)

Treatments Within Stages: The intermolar width of the first premolar extraction group at Stage A was found to be significantly different from the other two treatments. At Stage B, the non-extraction group was significantly different from the other two groups and this was again evident at Stage C.

Interaction

Analysis of variance showed a highly significant Mean Square for interaction between stages and treatments (P=0.003, see Table 7). As the intermolar widths for non-extraction and

first premolar extraction cases were maintained over stages, intermolar width for second premolar extraction cases was reduced significantly.

TABLE 7
INTERMOLAR WIDTH

(A) MEANS WITHIN TREATMENTS AND STAGES

STAGES	TREATMENTS			
	1st PM	2nd PM	NON-EXT	TOTAL
A (N)	30.03^{a}_{a} 4	34.19^{b}_{b} 10	34.24^{b}_{a} 10	33.52 24
B (N)	30.48^{a}_{a} 5	30.82^{a}_{a} 10	33.74^{b}_{a} 10	31.92 25
C (N)	29.45^{a}_{a} 5	30.30^{a}_{a} 11	34.44^{b}_{a} 10	31.73 26
TOTAL (N)	30.04 14	31.72 31	34.11 30	32.37 75

Means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level.

(B) ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MS	VR	P
STAGES	2	23.660	7.520	0.001
TREATMENTS	2	90.109	28.642	<0.001
STAGES.TREATMENTS	4	13.856	4.404	0.003
RESIDUAL	66	3.146		
TOTAL	74	6.630		

9.1.3.2.Discussion

Main Effects

(1) Stages: Intermolar width at the beginning of treatment is significantly larger than at the end of treatment and shows little change during the postretention period. This can be attributed to two factors; (a) forward movement of the first molar into a narrower section of the arch during correction of

Class II molar relationships and space closure, and (b) the use of Class II elastics which impart a lingual component of force to the buccal surface of the first molar.

Stages Within Treatments: No significant change in intermolar width in first premolar extraction cases (Fig. 11) reflects two characteristics of this treatment; (a) minimal forward movement required of the molar to due loss of arch length prior to treatment, or the unravelling of anterior crowding in a posterior direction, or the retraction of a proclined anterior segment, and (b) added stability afforded the molar by the adjacent second premolar to resist the lingual component of force imparted by Class II elastics.

The mean intermolar width of second premolar extraction cases is significantly reduced during treatment (Fig. 11). This reflects the considerable forward movement required in these cases and the greater vulnerability of the molar to the "lingual rolling" effect of Class II elastics.

In non-extraction cases, there is little change in the intermolar dimension (Fig. 11), although a tendency toward constriction during treatment is noted which may be due to Class II elastics once again, as it recovers during the postretention period.

(2) **Treatments:** The mean intermolar width over stages of first premolar extraction cases was found to be significantly smaller than that of second premolar extraction cases, which was significantly smaller than that of the non-extraction group. This reflects the more forward position of the first molar in a narrower section of the arch in the first and second premolar extraction cases due to anterior crowding, and following extraction prior to treatment. The influence of

forward molar position is particularly evident in the mean value of the first premolar extraction cases where more severe crowding and proclination in the anterior segment has resulted in arch length reduction prior to treatment (or vice versa).

Treatments Within Stages: The mean intermolar width of second premolar extraction cases at the beginning of treatment is no different to that of the non-extraction group (Fig. 11) indicating minimal forward drift of the molar prior to treatment due to little or no crowding in the anterior segment. However, of particular interest is the narrow intermolar width of the first premolar extraction group prior to treatment compared to the second premolar extraction group, indicating significant reduction in arch length due to anterior crowding and proclination, reflecting a substantial tooth-jaw size discrepency.

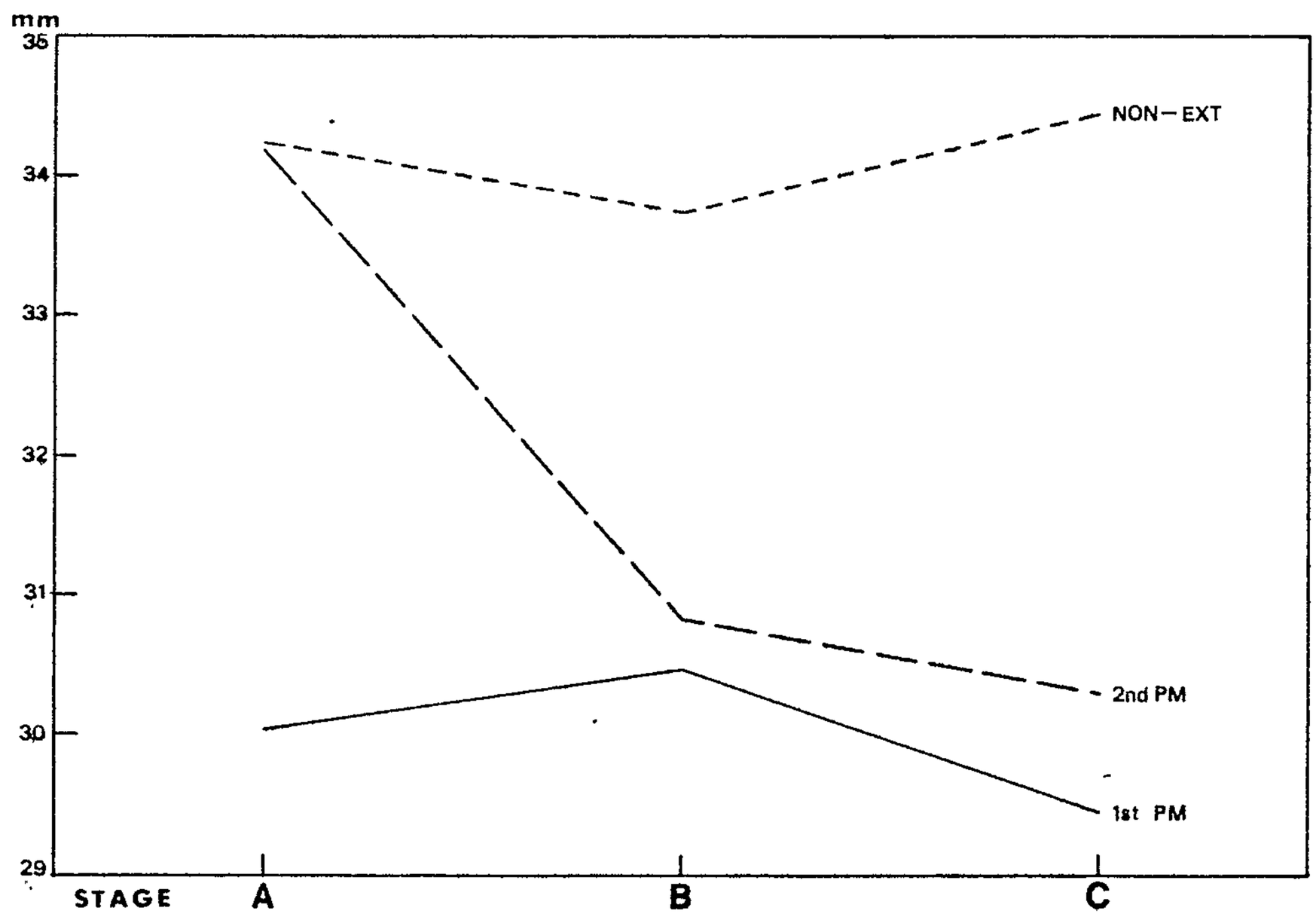
Consistent with previous observations, the mean intermolar widths of non-extraction cases are greater than those of first and second premolar extraction cases at the end of treatment and postretention, i.e. no significant forward movement of the molar occurs during treatment.

Although not significant, there is a tendency toward continued constriction of intermolar width in extraction cases during the postretention period (Fig. 11). This is analogous to the reduction of intercanine width observed during the postretention period for first premolar extraction cases where no expansion was evident during the treatment period. A similar explanation may be relevant, i.e. remodeling and reorganisation in the extraction site may alter the balance and expression of the stabilising influences of arch form.

Interaction

The decrease in intermolar width observed in second premolar extraction cases compared to intermolar width stability in non-extraction and first premolar extraction cases, reflects the significantly different antero-posterior movement of the molars prior to and during each treatment. Conversely, this also substantiates the implied antero-posterior and hence lateral movements of the canines.

FIGURE 11
INTERMOLAR WIDTH



9.1.4.DISCUSSION SUMMARY - ARCH WIDTH BY STAGES

It has been presumed that the greater pretreatment intercanine width recorded for first premolar extraction cases indicates a more forward, buccally tipped canine position. During treatment, the canines are retracted into what should be considered their correct position within the arch, but are

maintained at the same intercanine width. This intercanine width then constricts during the postretention period since the canine is not necessarily positioned in a "broader" section of the arch as is generally perceived.

The intercanine width of second premolar extraction cases is expanded during treatment to alleviate crowding. The relapse evident during the postretention period indicates that not only is this expansion unstable, but that the canines are not retracted during treatment.

Therefore, it is to be expected that the intercanine width of first and second premolar extraction cases relapse to the same stable dimension as they assume the same "correct" canine position. This would seem to substantiate the concept of an inviolate intercanine width.

The small magnitude of intercanine width changes observed between stages for each treatment indicates that the Begg technique maintains consistent and predictable control over this dimension.

In summary:-

1. First premolar and second premolar extraction cases result in intercanine width reduction and relapse respectively, of the same magnitude, likely for different reasons, and by different canine movement, during treatment and following retention.
2. Intermolar and intercanine widths in extraction cases tend to reduce following retention.
3. In non-extraction cases, intercanine and intermolar widths tend to remain stable during treatment and following retention.

9.2.MANDIBULAR ARCH WIDTH CHANGES DURING PERIODS

Outlyers were eliminated from the total sample (Tables 11, 12, 13) prior to the following analyses of variance of mandibular arch widths during periods (treatment, postretention). Since the following analyses are concerned with changes during periods, rather than absolute values at stages as in the previous analyses of variance, the criteria for elimination of outlyers differed from the previous analyses. That is, cases where inconsistent changes during periods would disproportionately influence the results were not included in the following analyses. Such cases included those with anterior spacing that were excessively constricted during treatment, and those with ectopically positioned first molars or canines that may incur excessive expansion or relapse.

9.2.1.INTERCANINE WIDTH - CUSP TIP

9.2.1.1.Results

Mean changes of intercanine widths measured at the cusp tip for treatments during the "treatment" period (B-A) and the "postretention" period (C-B) are summarised in Table 8. The relevant analysis of variance is also presented in this table. A positive value indicates an increase in dimension, whereas a negative value indicates a decrease.

Main Effects

(1) Periods: Mean changes of intercanine widths during treatment and postretention periods were highly significant (P=0.003, see Table 8).

Periods Within Treatments: First premolar and second premolar treatments showed significant differences between the changes recorded during the treatment and postretention periods. On the other hand there was no significant difference in mean change of intercanine widths between the two periods in the nonextraction group.

(2) Treatments: There were no significant differences between treatments over periods (P=0.841).

Treatments Within Periods: Although the differences of the relevant group means recorded for change in intercanine widths

TABLE 8
INTERCANINE WIDTH - CUSP TIP

(A) MEANS OF CHANGES WITHIN TREATMENTS AND PERIODS

	TREATMENTS			
	1st PM	2nd PM	NON-EXT	TOTAL
TREATMENT PERIOD	$+0.77^{a}_{a}$ 7	$+0.68^{a}_{a}$ 14	$+0.27^{a}_{a}$ 10	$+0.57_{a}$ 31
POSTRET'N PERIOD	-1.01^{b}_{b} 7	-0.46^{ab}_{b} 13	-0.03^{a}_{a} 10	-0.44_{b} 30
NET CHANGE	-0.24^{a} 7	$+0.22^{a}$ 14	$+0.24^{a}$ 10	-0.12 31

Means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level.

(B) ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MS	VR	P
PERIODS	1	16.283	9.738	0.003
TREATMENTS	2	0.290	0.173	0.841
PERIODS.TREATMENTS	2	2.381	1.424	0.250
RESIDUAL	55	1.672		
TOTAL	60			

during the postretention period were statistically significant, first premolar extraction cases tended to show greater reduction of intercanine width during this period than second premolar estraction cases. This occurred after similar increases diring the treatment period.

Interaction

Analysis of variance showed that interaction between periods and treatments was not significant (P=0.250).

9.2.1.2.Discussion

Treatments Within periods: There was no significant difference between the overall changes in intercanine width recorded for each treatment. Further, the net change over periods for each treatment approached zero (Fig. 12). From this observation, intercanine width would seem to be an inviolate dimension. This is consistent with previous Edgewise studies (Total sample net increase: non-extraction = +0.62 mm, extraction = +0.39 mm), although most of these studies showed greater net increase in this dimension followed by greater relapse for extraction and non-extraction cases than the present study (see Table 3).

Stages Within Treatments: First premolar extraction cases expanded during treatment and were then found to relapse during the postretention period by an amount greater than the original expansion (Fig. 12), the difference between the two stages being highly significant. BISHARA et al (1973) reported exactly the same expansion for intercanine width (0.77 mm) in their first premolar extraction sample (Edgewise

treatment), followed by only half the relapse recorded in this study.

A pattern similar to first premolar extraction cases was found in second premolar extraction cases, varying only in degrees of significance. This indicates a considerable anomaly when compared to the previous analysis of variance for intercanine width [stages] where intercanine width in first premolar extraction cases was found to be not signficantly different at the pretreatment, end of treatment or postreatment stages (more specifically, intercanine width did not change during treatment and tended to decrease following retention).

The different behaviour of first premolar extraction cases observed between the two analyses can be explained by the method of sampling. The sample for study of arch width at stages was analysed with a general linear model approach using regression to eliminate outlyers. As a result, two cases (M.S. and J.W., see Table 11) were eliminated from this first premolar extraction sample. These cases had pretreatment intercanine widths of 22.10 mm. and 21.85 mm. respectively, compared to the mean for the remainder of this group of 26.00 mm. More importantly, they were the two cases that expanded a disproportionate amount (+2.19 mm. and +3.52 mm. respectively), compared to the remainder of the first premolar extraction group (expansion ranging from -0.83mm. to +0.68 mm.). They were not excluded from the study of arch width changes during periods. The results of the first premolar extraction group for the analysis of variance [periods] was probably disproportionately influenced by these two cases. Since the canines for these two cases were not

ectopically placed, the constricted pretreatment intercanine widths may be due to:-

1. A smaller mandible and/or dental arch.
2. More severe incisor crowding with the canines assuming a position in the narrow anterior curve of the dental arch.
3. Excessive lingual tipping of the canines.

It is therefore apparent that first premolar extraction cases with constricted pretreatment intercanine widths behave differently from those with canines that have drifted forward with perhaps slight buccal tipping. That is, the former seem to behave in a similar manner to canines in second premolar extraction cases. However, the observation that both patterns of canine behaviour for first premolar extraction cases result in decrease of intercanine width following retention, is consistent with results reported by LEVIN (1977; Begg treatment, first premolar extraction sample) who found that "mandibular intercanine width decreased in the posttreatment period, irrespective of whether an increase or a decrease occurred in the treatment period."

The possible interaction between pretreatment intercanine width and changes in widths during subsequent periods cannot be answered from the present study due to sample size and insufficient data. However, this aspect warrants investigation in order to further establish and clarify predictable patterns of canine movement during treatment for and within different extraction groups.

Although the analysis of changes of intercanine widths within periods in the second premolar extraction group produced results which were similar to those obtained by

analysis of intercanine widths within stages, further evidence of interaction between pretreatment intercanine width and change of width within periods was observed. Three cases in this group (J.L., L.F., and S.L.) had considerably constricted pretreatment intercanine widths (22.31, 19.61. and 20.37 respectively) compared to the remainder of the group (mean=25.57mm.). Rather than the significant increase of intercanine width observed during treatment followed by relapse during the postretention period which was recorded for the group as a whole in both analyses of variance, the constricted cases were observed to increase during treatment and continue to increase during the postretention period.

Similarly, closer inspection of non-extraction cases revealed that where anterior spacing occurs, as for cases J.K. and P.J., the intercanine width is constricted during treatment followed by a variable amount of expansion during the postretention period. These two cases were eliminated from the study of intercanine widths at stages due to anterior spacing. This seems to be associated with a large pretreatment intercanine width.

It is interesting to note the larger increases in intercanine width during Edgewise treatment reported in the literature (see Table 3) for all extraction and non-extraction samples, except the extraction sample of BISHARA et al. This may reflect three aspects of Begg treatment when compared to Edgewise treatment:-

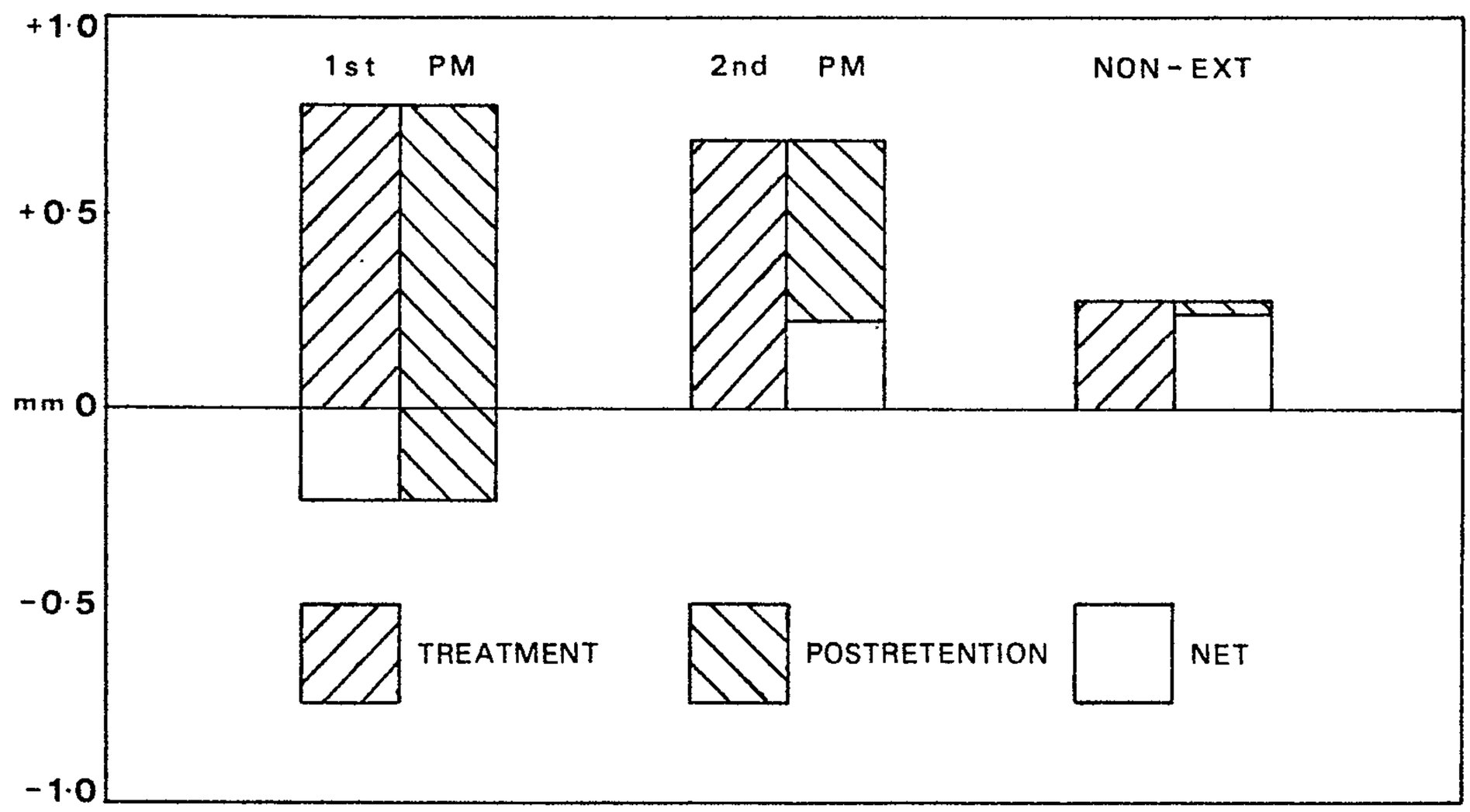
1. Good anchorage control - allowing canines to be adequately retracted rather than expanded.
2. Control of intercanine width through a "flatter" arch-form in the canine region, i.e. expanded Begg

arch-forms in light round wires, when inserted into the buccal tubes, restrict canine expansion.

3. A greater liklihood to extract in borderline cases, consistent with basic Begg philosophy.

However, these comparisons may be tempered in some instances since some of the Edgewise samples would have been influenced by the placement, and relapse following removal, of incisor bands prior to the introduction of bonded brackets.

FIGURE 12
INTERCANINE WIDTH - CUSP TIP
CHANGES DURING PERIODS WITHIN TREATMENTS



9.2.2.INTERMOLAR WIDTH - MESIOLINGUAL CUSP

9.2.2.1.Results

The means and analysis of changes in intermolar widths for treatment (B-A) and postretention (C-B) periods are presented in Table 9. A positive value indicates an increase in dimension, whereas a negative value indicates a decrease.

Main Effects

(1) Periods: Analysis of variance showed no significant difference for change in intermolar width between treatment and postretention periods over all treatments (P=0.313). However, there is a tendency toward greater reduction of intermolar width in the treatment period than the postretention period.

Periods Within Treatments: First premolar and second premolar treatments produced significantly different reductions of intermolar widths during the treatment and postretention periods, whereas no significant difference between these periods was recorded for the non-extraction group.

(2) Treatments: The differences in mean change in intermolar widths for treatments pooled over both periods are highly significant (P=0.006, see Table 9).

Treatments Within Periods: The mean change during treatment of intermolar width in first premolar and second premolar extraction cases, was significantly different to that of non-extraction cases. Although not significant at the 5% level, there is a tendency for greater reduction of intermolar width during the treatment period in second premolar extraction cases than first premolar extraction cases (Fig. 13).

Although the differences between treatments for change in intermolar width during the postretention period are not statistically significant, again the tendency is for greater reduction of this dimension in the second premolar extraction cases.

Differences between each treatment for net intermolar width

change were highly significant (P<0.001), with second premolar extraction cases showing the greatest overall reduction of intermolar width.

Interaction

Analysis of variance indicated that interaction only approached significance at the 10% level (P=0.159). From the Table of Means it can be seen that while the first and second premolar extraction cases showed a significant decrease in intermolar width over periods, no such trend was observed in the non-extraction group.

TABLE 9
INTERMOLAR WIDTH

(A) MEANS OF CHANGES WITHIN TREATMENTS AND PERIODS

	TREATMENTS			
	1st PM	2nd PM	NON-EXT	TOTAL
TREATMENT PERIOD	-1.35^{b}_{a} 7	-2.35^{b}_{b} 14	$+0.41^{a}_{a}$ 10	-1.23_{a} 31
POSTRET'N PERIOD	-0.53^{a}_{a} 7	-1.04^{a}_{a} 14	-0.29^{a}_{a} 10	-0.68_{a} 30
NET CHANGE	-1.87^{b} 7	-3.39^{c} 14	$+0.12^{a}$ 10	-1.91 31

Means within rows and columns bearing the same superscripts and subscripts respectively, are not significantly different at the 5% level.

(B) ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MS	VR	P
PERIODS	1	3.277	1.037	0.313
TREATMENTS	2	17.969	5.688	0.006
PERIODS.TREATMENTS	2	6.014	1.904	0.159
RESIDUAL	56	3.159		
TOTAL	61			

9.2.2.2.Discussion

Although the results derived from analysis of variance [means of changes] were based on a slightly different sample to the analysis of variance [mean values], as was discussed for intercanine width, the results and hence discussion do not differ greatly.

Main Effects

(1) **Periods:** A similar trend is evident for intermolar width changes for stages over all treatments in both analyses, i.e. this dimension is reduced more during treatment than following retention.

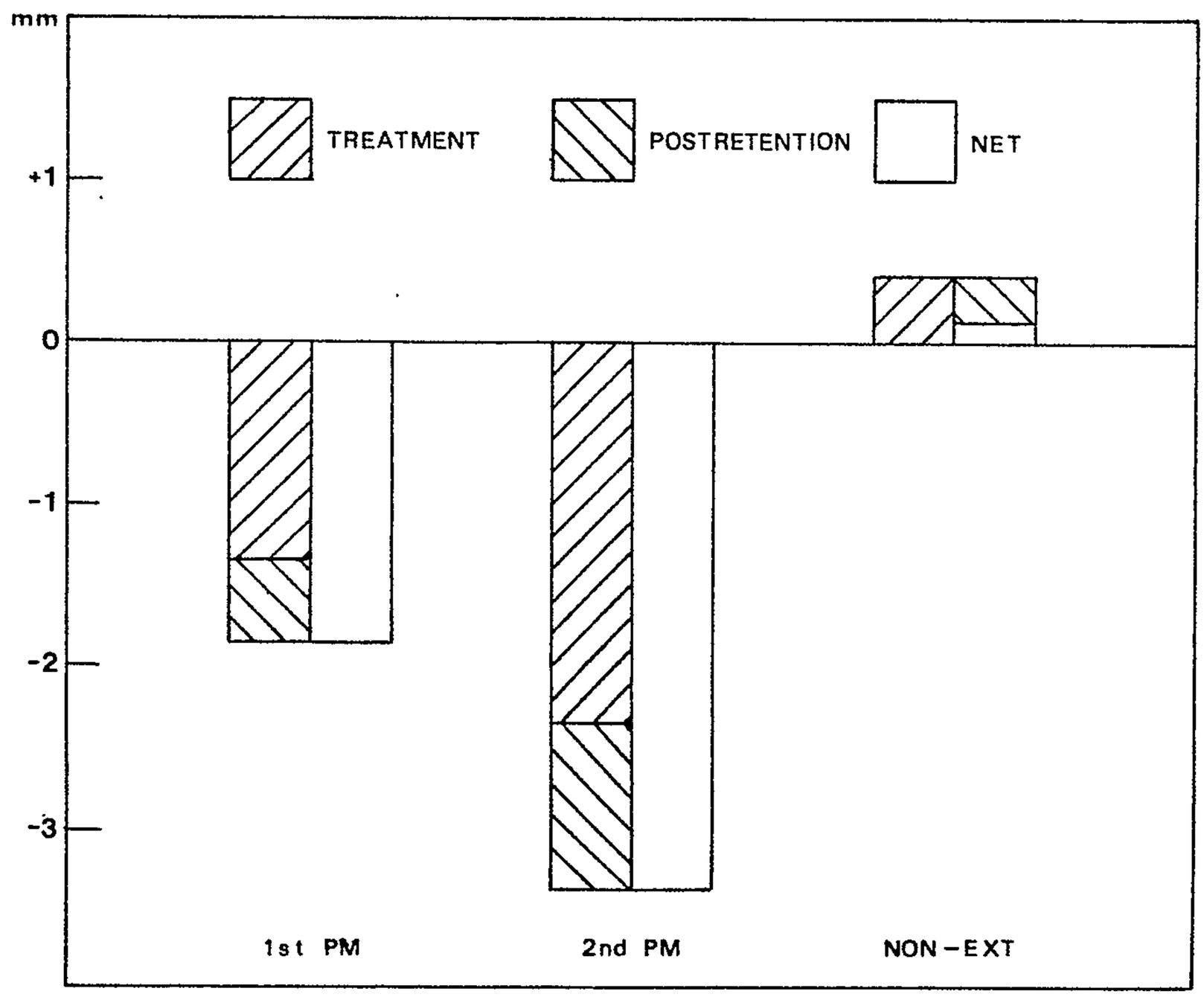
Periods Within Treatments: Both first premolar and second premolar extraction cases showed greater reduction of intermolar width during treatment than during the postretention period with the difference being significant in second premolar extraction cases (Fig. 13). These results are consistent with analysis of variance [stages], and consistent with the derived Edgewise treatment Total Sample extraction cases (see Table 4), although individual studies reported in the literature showed some variation from this pattern for extraction cases. More significantly, the stability of intermolar width during treatment and following retention for non-extraction cases found in this study, was not at all consistent with the increase during treatment and following retention reported in the literature for Edgewise treatment.

(2) **Treatments:** Significant differences in intermolar widths are indicated for each treatment over all periods (Fig. 13). While the net change for first premolar and second

premolar extraction cases resulted in reduction of intermolar width similar to that reported in the literature, non-extraction cases showed no significant net change over all stages. This does not concur with results reported in the literature, which indicate a significant net increase in intermolar width in non-extraction cases.

Treatments Within Periods: Although the differences between intermolar width reduction for first and second premolar extraction cases were not significant either during treatment or during the postretention period, the trend is for less reduction in both instances for first premolar extraction cases. This is substantiated by the significant difference in reduction recorded over all periods for these two treatments and supports the conclusions regarding molar movement and the implications concerning associated canine retraction derived from analysis of variance [mean values].

FIGURE 13
INTERMOLAR WIDTH
CHANGES DURING PERIODS WITHIN TREATMENTS



9.2.3.COMPARISON OF TREATMENTS

Table 10 shows the effect of treatment period on intercanine and intermolar widths within treatments (B-A=treatment period, C-B=postretention period, C-A=net change). This table is intended to present a convenient summary of both intercanine and intermolar width changes recorded in this study with statistical significance assigned to the difference between dimension and period. Hence direct comparison between canine and molar width increase or decrease within each treatment is evident rather than having to make deductions based on the previous analyses of variance for each tooth (dimension) individually.

TABLE 10

MEANS OF CHANGES WITHIN DIMENSIONS AND PERIODS FOR EACH TREATMENT

DIMENSION	B – A	C – B	C – A
FIRST PREMOLAR EXTRACTION (MS^{res}=4.51)*			
INTERCANINE WIDTH	$+0.77^{a}_{a}$ 7	-1.01^{a}_{a} 7	-0.24 7
INTERMOLAR WIDTH	-1.35^{a}_{a} 7	-0.53^{a}_{a} 7	-1.87 7
SECOND PREMOLAR EXTRACTION (MS^{res}=2.48)*			
INTERCANINE WIDTH	$+0.68^{a}_{a}$ 14	-0.46^{a}_{a} 14	+0.22 14
INTERMOLAR WIDTH	-2.35^{b}_{b} 14	-1.04^{a}_{a} 14	-3.39 14
NON-EXTRACTION (MS^{res}=0.94)*			
INTERCANINE WIDTH	$+0.27^{a}_{a}$ 10	-0.03^{a}_{a} 10	+0.24 10
INTERMOLAR WIDTH	$+0.41^{a}_{a}$ 10	-0.29^{a}_{a} 10	+0.12 10

*D.F.: 1st PM=24, 2nd PM=51, Non-exo=36

This analysis confirms the different effect of first and second premolar treatment on the relationship between intercanine and intermolar width changes, particularly during the treatment period.

CHAPTER 10
CONCLUSIONS

10.1.MANDIBULAR ARCH WIDTH AT STAGES

10.1.1.Intercanine Width - Cusp Tip

From mean values of intercanine width recorded at the cusp tip at successive stages (Table 5, Fig. 3), the following trends were observed:-

1. The intercanine width of first premolar extraction cases remains constant during treatment but tends to decrease following retention.
2. The intercanine width of second premolar extraction cases is expanded during treatment and relapses almost to the original dimension following retention.
3. The intercanine width of non-extraction cases remains constant during treatment and following retention.

10.1.2.Intercanine Width - Buccal Surface

Relating means of intercanine width measured at the buccal surface with those for the cusp tip dimension gives an indication of the different axial movements occurring for different treatments (Tables 5, 6; Figs. 5, 6, 7). These movements can be summarised as follows:-

1.In first premolar extraction cases, the canines tend to

be uprighted during treatment, followed by a bodily reduction of intercanine width following retention.

2. In second premolar extraction cases, bodily buccal movement of the canines occurs during treatment, followed by lingual tipping of the crowns and bodily relapse following retention.

3. Minimal movement of the canines occurs during and after treament of non-extraction cases. A tendency toward marginal bodily buccal movement is evident.

10.1.3.Intermolar Width

Intermolar width changes generally reflect pretreatment conditions and treatment changes in the anterior segment. Interpretation of intermolar widths (Table 7; Figs. 11, 13) derive the following conclusions:-

1. The absence of intermolar width reduction and hence no forward movement of first molars during treatment in first premolar extraction cases reflects significant retraction of the canines in order to align and/or retract the canines and incisors.

2. Significant intermolar width constriction and hence forward movement of first molars during treatment in second premolar extraction cases, reflects (a) the necessity to maintain incisor position due to profile considerations, or (b) minimal crowding.

3. Points 1 and 2 further validate previous interpretation of intercanine width changes, i.e. canines in first premolar extraction cases are not expanded due to retraction to alleviate crowding and protrusion, whereas

canines in second premolar extraction cases are expanded in order to minimise retraction.

4. The intermolar width of non-extraction cases remains constant during treatment and following retention.

10.2.MANDIBULAR ARCH WIDTH DURING PERIODS

Comparison of mean changes during periods (Table 8, Fig. 12) with mean widths at stages (Table 5, Fig. 3) revealed the following patterns of canine movement for the three treatments investigated:-

1. First premolar extraction cases with canines that have migrated anteriorly tend to be retracted during treatment without change in the intercanine dimension and then constrict during the postretention period. A net decrease in intercanine width is observed over all stages.

1a. First premolar extraction cases with constricted pretreatment intercanine width, tend to expand during treatment and then relapse to varying degrees during the postretention period. Insufficient cases were analysed to determine the amount of net expansion that can be expected.

2. Second premolar extraction cases with canines aligned within the arch tend to expand during treatment and then relapse almost to the original intercanine dimension. There is little net change in intercanine width over all stages.

2a. Second premolar extraction cases with constricted pretreatment intercanine width, tend to expand during

treatment and then continue to expand during the postretention period. From the number of cases analysed in this study, it is not possible to quantify or determine the consistency of the net effect of this observation.

3. The intercanine width of non-extraction cases with canines aligned within the arch, show very little change of intercanine width during or following treatment.

3a. Non-extraction cases with expanded intercanine width associated with anterior spacing tend to be constricted during treatment and then expand to varying degrees during the postretention period. Insufficient cases were analysed in this study to determine the net reduction of intercanine width over all stages.

10.3.RECOMMENDATIONS

10.3.1.Clinical Implications

(1) It is apparent that the method of treatment is not the only factor influencing canine behaviour during and after treatment. It would seem that the pretreatment intercanine dimension also has a significant bearing on subsequent canine movements. This dimension, related to that of the apical base, should be used as a guide in evaluating treatment objectives in relation to canine retraction and expansion.

(2) It is apparent that the extraction versus non-extraction argument doesn't entirely resolve the expansion issue. Mean values of intercanine width changes for treatments over all stages would suggest that the intercanine dimension is

inviolate. However, consideration of pretreatment intercanine width can define circumstances where this dimension may be expanded and maintained.

10.3.2.Further Investigation

(1) The interpretation of intercanine width changes during treatment for first and second premolar extraction cases is based partially on the premise that the canines in second premolar extraction cases are not substantially retracted, whereas the canines in first premolar extraction cases are retracted. Evidence for this is derived from changes in intermolar width. However, this should be further assessed with cephalometric analysis.

(2) Intercanine width measured at the buccal surface was used, in association with intercanine width measured at the cusp tip, to illustrate axial canine movements in the transverse plane. The method used to derive the buccal surface measurements was subject to greater error than measurements taken from the cusp tip. A more satisfactory method of recording this measurement may be sectioning duplicate models transversely through reproducible points at the cusp tip. This procedure, when correlated with cephalometric determination of antero-posterior movements, would give a valid three dimensional representation of canine movements for different extraction treatments.

(3) Further investigation is required to clarify the interaction between the method of treatment and pretreatment intercanine width in relation to patterns of intercanine width changes during and following treatment. A larger sample is

required to compare constricted and "normal" first and second premolar extraction cases, and constricted, "normal" and spaced non-extraction cases.

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APPENDIX I

STASTICAL FORMULAS

The formulas used in the statistical analyses presented in this thesis are:

OBSERVATIONS = n

DEGREES OF FREEDOM (df) = n - 1

SUM OF SQUARES (SS) = $\Sigma^1(X^1 - \bar{x})^2$

MEAN SQUARE (MS, Variance) = $\frac{\Sigma^1(X^1 - \bar{x})^2}{n - 1} = \frac{SS}{df}$

STANDARD DEVIATION (s) = $\sqrt{\frac{\Sigma^1(X^1 - \bar{x})^2}{n - 1}}$

STANDARD ERROR OF MEAN = $\sqrt{\frac{s^2}{n}}$, where s^2 = Error MS

Sd = Standard Deviation of Difference Between Means

$= \sqrt{\frac{s^2}{n^1} + \frac{s^2}{n^1}}$

L.S.D.(0.05) = Least Significant Difference

= t(0.05, Error df)Sd

FISHER VARIANCE RATIO (F, VR) = $\frac{\text{MS (effects)}}{\text{MS (error)}}$

PROBABILITY (P) = F df(effects)/df(error)

APPENDIX II

MEASUREMENTS (X^1)

TABLE 11

FIRST PREMOLAR EXTRACTION CASES

	INTERCANINE WIDTH (Cusp Tip)			INTERCANINE WIDTH (Buccal Surface)			INTERMOLAR WIDTH (M-L Cusp)		
NAME	A	B	C	A	B	C	A	B	C
S.S.	25.59	25.34	25.40	29.40	30.62	29.79	29.95	30.34	29.08
S.C.	26.07	26.44	24.65	28.95	30.61	29.35	30.51	32.64	30.31
M.S.	22.10	24.29	23.72	26.20	30.26	29.61	32.27	28.79	29.38
M.H.	25.97	26.65	25.96	30.64	30.53	30.57	35.54	29.59	31.97
G.R.	27.10	26.27	25.92	28.52	28.83	28.55	28.86	31.71	27.79
K.W.	25.27	25.01	23.78	29.24	29.20	28.30	30.79	28.12	28.12
J.W.	21.85	25.37	22.88	27.16	29.80	27.73	29.90	27.20	28.05

TABLE 12

SECOND PREMOLAR EXTRACTION CASES

	INTERCANINE WIDTH (Cusp Tip)			INTERCANINE WIDTH (Buccal Surface)			INTERMOLAR WIDTH (M-L Cusp)		
NAME	A	B	C	A	B	C	A	B	C
V.J.	24.44	24.92	24.09	28.41	28.87	28.42	31.92	30.17	29.16
L.J.	23.63	25.86	24.95	27.43	29.93	29.37	32.45	33.50	30.96
H.B.	25.12	27.15	26.19	27.85	30.88	30.03	34.70	31.69	31.17
K.D.	23.68	24.27	23.48	28.28	29.23	28.27	29.70	28.68	27 01
J.L.	22.31	24.02	24.89	25.09	29.31	28.89	34.37	30.85	30.73
F.P.	26.17	26.37	25.39	29.79	30.48	29.80	34.85	30.81	29.75
M.C.	23.59	28.50	27.43	28.90	32.78	32.25	33.05	31.89	30.73
L.F.	19.61	22.19	22.99	26.27	28.58	28.55	30.19	30.05	28.31
A.M.	24.52	23.76	23.64	25.79	27.31	26.55	34.23	27.92	28.69
F.S.	26.15	24.92	24.97	30.78	30.35	30.29	34.26	30.25	29.98
L.N.	26.49	26.45	25.79	31.84	31.74	31.34	35.10	31.46	32.34
S.J.	25.83	26.66	25.88	29.97	29.51	30.15	35.41	31.81	30.71
S.L.	20.37	21.75	22.22	25.83	28.64	28.63	30.73	27.19	27.85
C.W.	27.50	26.11	25.66	31.62	31.87	31.53	33.51	32.53	29.77
P.C.	24.85	27.23	26.65	29.77	31.67	31.65	36.59	35.24	32.85
P.V.	30.50	27.18	28.38	32.86	31.64	32.27	35.64	32.72	32.74

TABLE 13

NON - EXTRACTION CASES

	INTERCANINE WIDTH (Cusp Tip)			INTERCANINE WIDTH (Buccal Surface)			INTERMOLAR WIDTH (M-L Cusp)		
NAME	A	B	C	A	B	C	A	B	C
J.K.	28.86	24.75	26.36	32.03	28.93	30.16	37.17	34.39	35.66
S.P.	24.75	24.45	24.47	28.29	28.35	28.55	31.97	30.94	31.73
S.E.	25.36	25.78	25.13	28.69	28.83	28.90	35.45	38.14	36.87
P.J.	27.13	24.12	26.81	31.03	28.91	30.07	37.23	36.17	37.01
P.G.	26.23	26.25	26.09	31.14	30.30	30.79	34.53	34.68	34.57
C.M.	26.59	26.07	27.17	28.91	28.36	29.52	32.35	32.67	32.86
A.H.	27.29	27.60	27.14	30.25	30.53	30.01	32.43	32.90	32.43
R.H.	25.85	25.49	25.10	28.25	29.48	29.37	32.11	32.75	32.73
B.K.	24.40	24.46	24.87	29.18	28.12	29.03	35.93	36.87	36.14
J.H.	23.89	25.93	26.13	28.92	29.51	30.25	36.37	35.92	36.37
S.R.	24.14	23.24	23.49	27.62	26.57	26.86	30.11	31.71	29.10
M.D.	24.40	26.31	25.73	27.93	29.37	29.07	34.01	32.76	33.68