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A CEPhALOMETRIC STUDY OF SHORT TERM MANDIBULAR ADAPTATIONS TO BITE OPENING WITH A MAXILLARY BITE PLATE
A CEPHALOMETRIC STUDY OF SHORT TERM MANDIBULAR ADAPTATIONS TO BITE OPENING WITH A MAXILLARY BITE PLATE

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A Thesis submitted in partial requirement for the degree of MASTER OF DENTAL SCIENCE

Department of Preventive Dentistry
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1979
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Finally, my gratitude is to my parents, who have always encouraged me to exploit to the full what little talents I may possess.

Morris Rapaport
Sydney
November 1979.
"Ah! don't say that you agree with me. When people agree with me I always feel that I must be wrong."

Oscar O'Flahertie Wills Wilde
from The Critic as Artist.

"Persons attempting to find a motive in this narrative will be prosecuted; persons attempting to find a moral in it will be banished; persons attempting to find a plot in it will be shot."

Mark Twain (S.L. Clemens)
introduction to Huckleberry Finn.
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Introduction
INTRODUCTION

The hypothesis that prompted this investigation was developed following the identification of a number of problems, and my review of findings and recommendations related to those problems.

THE PROBLEMS

1. Cases exhibiting low mandibular plane angles, and particularly Class II, Division 2 cases, have an unfavourable prognosis for the permanent correction of the deep overbite, that is usually associated with the condition. This problem has been voiced by a number of eminent Sydney orthodontists, who are also tutors in the Sydney University Orthodontic Clinic. Their experience has been that there is often a return towards the original deep overbite following routine multibanded treatment in low mandibular plane angle, and Class II, Division 2 cases. More recently, at the Begg Society Study Group Meeting (Sydney 1979), a case presenting particular problems of bite opening was discussed. On the basis of the pre-treatment and progress cephalographs, which revealed that the incisors had been intruded to the limits of the symphysis and that there was a low mandibular plane angle, it was suggested that anatomical limitations prevented further bite opening, and that the best possible compromise result had been achieved.
2. The permanent correction of certain malocclusions in adults can present dentists with insurmountable problems. This assertion is exemplified by the case of a woman in her thirties with a Class II, Division 2 malocclusion and a traumatic deep bite with gingival stripping. (figure 1a) Following consultation with specialists in the fields of orthodontics, oral surgery, prosthodontics and restorative dentistry, the prognosis for an acceptable, stable correction by any means, was deemed to be unfavourable. The eventual compromise treatment recommended was the extraction of the lower anterior teeth, followed by the fitting of a removable prosthesis. This case was presented during a lecture to graduate orthodontic students by Professor G. Stacey of the Department of Oral Medicine and Oral Surgery, Faculty of Dentistry, University of Sydney. Professor Stacey holds qualifications in both the specialties of oral surgery and orthodontics. Dr. J. Highfield, senior lecturer in the University Periodontic Department, has shown a similar case with the same unfavourable prognosis. (figure 1b)

It has been inferred that the above identified problems are essentially skeletally determined. This then suggests that orthopaedic therapy may provide the solution.
FIGURE 1a (top three)

Young woman with Class II Division 2 malocclusion and traumatically deep overbite.

(Courtesy Prof. G. Stacy)

FIGURE 1b (bottom two)

Gingival stripping (left) associated with traumatically deep overbite (right), in a young man of twenty two years of age.

(Courtesy Dr. J. Highfield).
THE FINDINGS:

1. Relatively large orthopaedic movements are possible, at least in animals, using simple functional appliances. (Harvold 1968 and McNamara 1973).

2. There is a direct relationship between the maturation level of an animal and the extent of skeletal adaptation to functional appliance therapy. Put simply: the younger the animal, the greater the orthopaedic effect. (McNamara 1973)

THE RECOMMENDATIONS:

1. The deep bite associated with pronounced forward mandibular rotation can be prevented by means of a bite plate, introduced before puberty. (Bjork 1969)

2. Orthodontists take up the challenge to find the means and methods of effecting significant skeletal change in man. (Graber and Neumann 1977 P.163, 164)

and hence:

THE HYPOTHESIS:

That bite plate therapy, if commenced as early as possible and continued (perhaps just at nights) until growth is
complete, will turn a forward mandibular growth rotation into a backward rotation; and in so doing will vastly improve the prognosis for any subsequent multibanded treatment of these difficult cases exhibiting the unfavourable growth pattern.

There are a number of assumptions implicit in the hypothesis.

These are:

1. That an early prediction of the cases that will develop a pronounced forward mandibular rotation, is possible. Bjork (1969) has suggested a method which enables this prediction to be made. (Table 1)

2. That we ought to be treating the skeletal problem and not just the dental symptoms; that is, we should change the direction of rotation, rather than just effecting orthodontic change, and in so doing we will improve the prognosis.

3. That multibanded appliances have very little effect upon basal structures, and are only capable of orthodontic change, as distinct from orthopaedic change. (Williams 1970)

4. That the bite plate has the propensity to initiate a backward mandibular rotation; or at least prevent the continuation of a forward rotation.
TABLE 1

Listing Bjork's (1969) seven specific structural features of extreme growth rotation. Not all seven signs will be present in any one individual but the greater the number present, the more reliable will be the prediction.

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<tr>
<td>7. Anterior lower face height</td>
<td>Short</td>
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TESTING THE HYPOTHESIS

To properly test the hypothesis a long term study of a large group of young patients evidencing some or all of Bjork's (1969) seven structural signs for predicting significant forward growth rotation (Table 1) would be required and divided into experimental and control groups. As far as is possible, the two groups would differ in only one regard: in addition to the usual multibanded treatment carried out to treat forward rotaters at approximately twelve years of age, the experimental group would also be subjected to long term bite plate therapy prior to, and subsequent to the banded treatment. A comparative follow-up evaluation of the treatment outcome in the two groups would then be necessary, particularly in regard to the depth of the overbite, in order to assess the original premise of a more favourable prognosis for the bite plate group.

THE PRELIMINARY INVESTIGATION

For obvious reasons, such as the length of time involved in such a study and the difficulty in immediately procuring a sufficient number of suitable patients, this present investigation does not attempt to test the hypothesis.
However, some of the assumptions implicit in the hypothesis, which have been previously described, require investigation prior to embarking upon the much more involved study.

Testing the assumption that the bite plate has the propensity to initiate a backward mandibular rotation, in the short term, forms the basis of this study.

Indirect evidence of mandibular postural adaptation to bite plate therapy, and mandibular incisor adaptation, will also be assessed.
Terminology
Description &
Types of Bite Plates
TERMINOLOGY

Bite plane, bite plate and bite block have been listed by Sleichter (1954) as terms descriptive of a variety of appliance used in orthodontic therapy.

Ramfjord and Ash (1971 P.245) point out that "The terms 'bite plates' and 'occlusal splints' are often used interchangeably, but the term 'bite plate' should be used only for Hawley type of appliances and the term 'occlusal splints' for those appliances that brace and hold together several teeth".
DESCRIPTION OF BITE PLATES

Moyers (1973 P.690) has described bite plates in the following manner:

1. The plate is made of acrylic resin.
2. It includes a shelf against which only certain teeth can occlude.
3. In the maxilla, this shelf lies behind the incisors and only the mandibular incisors meet it; all other teeth are kept from occlusion.
4. Bite plates can be flat or sloping to tip or deflect selected teeth out of position.
5. Anchorage is supplied by the mucosa and teeth.
6. Springs can be incorporated for movement of teeth.
TYPES OF BITE PLATES

There are a number of different bite plate designs. Ramfjord and Ash (1971 P.245), Moyers (1973 P.690) and others have described some of these.

1. THE MAXILLARY FLAT BITE PLATE

This design incorporates a flat plateau of acrylic built up behind the anterior teeth to which only the lower incisor teeth are contiguous. Clasps, usually Adams clasps around molars and/or bicuspids, provide retention. If the design incorporates a labial archwire and/or elastic, the appliance is often referred to as the Hawley retainer. It can serve as both a diagnostic and treatment appliance, since tooth interferences are removed enabling the mandible to adopt an unhindered position. As the incisors abrade the bite plate platform, it is sometimes necessary to have it resurfaced. Resurfacing is less often necessary if heat cure rather than cold cure acrylic is used.

There have been a number of criticisms levelled at this particular bite plate design. Ramfjord and Ash (1971 P.245) have said that these types of appliances tend to traumatize the gingival tissues. As evidence they have shown a
photograph of inflammation around the lingual gingival margins of the maxillary anterior teeth, presumably caused by occlusal forces being transmitted to these tissues via the bite plate platform.

Another possible design criticism could be directed at the bite plate's retentive clasps which Belger (1956) suggested could have a restraining effect upon molar elevation.

Sved (1944) mentioned what he considered a serious disadvantage of the Hawley bite plate. He believed it was possible for the upper anteriors to elongate and be moved labially by the wedging action of the bite plate during occlusal loading. He did not, however, present supportive evidence.

2. THE SVED PLATE (SVED 1944) (fig.2)

In this modification of the bite plate the acrylic is extended over the incisal edges of the maxillary anterior teeth, rendering it a partially tooth-borne appliance. The incisal covering provides a surprising amount of retention, so that clasps are unnecessary in most instances. According to Ramfjord and Ash (1971 P.246), forces are applied to the anterior teeth in an axial direction, but
FIGURE 2 Bite Plates

A. Sved plate

B, C, D, E. Sidlow hollow incline bite plane

(B) cross section

(C) in the mouth

(D) method of construction

(E) completed appliance

(From Moyers 1973 p 691).
there is doubt as to whether this is in fact the case. The appliance is simple to construct, although Moyers (1973 P.690) suggests that the orthodox flask curing method be used, since a strong acrylic is needed. When made of clear acrylic it is relatively aesthetic, rendering unnecessary Graber's (1961) modification in which incisal hooks are used instead of acrylic coverage.

Callaway (1940) has suggested that in Class II, Division 2 cases, it may be preferable to have the wedging action of a Hawley bite plate operating to tip retroclined incisors labially. If this occurs at all, it would presumably be a minor action.

A problem might arise if a Sved plate were inserted during the early eruption phase of the maxillary canine because its eruption path changes to one that is parallel with the roots of the lateral incisors. For canine deflection to occur, the lateral incisors must be free to move.

3. SIDLOW HOLLOW BITE PLANE (fig.2)

This is a maxillary bite plane with an open space behind the maxillary incisors. It is indicated when there is extreme labioversion of the maxillary incisors. Elastic
traction can be applied to retract these teeth along the hollow, inclined plane. Moyers (1973 P.692).

Like the bite plate; the Oliver guide plane, the Andresen, the propulsor, the equi-plane and other appliances appear to correct deep anterior overbite by allowing the posterior teeth to erupt, while restraining the lower anterior teeth. For this reason some of these appliances are also described hereunder.

4. **OLIVER GUIDE PLANE**

This is a precision fixed auxiliary often used in conjunction with the labio-lingual technique in the treatment of Class II malocclusions. It is not specifically a bite plate in that the lower incisor teeth do not forcefully engage it.

The lower arch is guided anteriorly to the guide plane through contact between a lower fixed lingual arch and the guide plane. Molars and premolars can develop vertically, thereby reducing the overbite. Oliver (1945).

5. **THE PROPULSOR**

The propulsor is a hybrid appliance with features of both the Andresen and the oral screen and with which no wire
configurations are used. The acrylic between the occlusal surfaces of the first molars serves to stabilise the appliance when therapy is initiated. As treatment progresses, however, this acrylic is progressively removed to allow for unhindered eruption of the molars and resultant reduction of the deep overbite, if it exists. Graber and Neumann (1977 p.115).

Although the Propulsor is primarily concerned with postero-anterior correction, it nevertheless has some features, common to the maxillary bite plate, which aid in overbite reduction.

6. THE EQUI-PLANE

Schwarz and Gratzinger (1966 p.231) have said that the equi-plane which is a modification of the Andresen, is one of the more successful functional appliances for treating excessive overbite. It consists of an upper palatal plate, with a wire platform contacting the incisal edges of the upper anteriors. Metal springs connect with a lower bite plane and induce jaw closure. The recoil of the springs tends to depress the anterior teeth. The posteriors are held out of contact and can develop vertically to aid in overbite reduction.
History of Bite Plates
HISTORY OF BITE PLATES

Kelsey (1938) and Sleichter (1954) have outlined a history of the bite plate. John Hunter in 1771 described a lower inclined plane the purpose of which was to move lingually locked incisors labially. In 1803 Joseph Fox advocated the use of a bite block over the posterior teeth to remove the forces of occlusion as a necessary preliminary to orthodontic movement. In 1883 Henry Clay Quinby illustrated a dual purpose maxillary bite plate, its first purpose being to allow increased eruption of posterior teeth and thereby reduce the anterior overbite. Secondly, he concluded that the overbite reduction would provide the space necessary for the lingual movement of maxillary incisors. W.G. Bonwill's maxillary bite plate, described in 1889, was not only supposed to allow further eruption of molars and bicuspids, but was also assumed to depress the lower incisors.

Salzmann (1966, p. 937) credits N.W. Kingsley with having introduced the bite plate into the United States in 1879. The main purpose of the plate which Kingsley (1892) described was "to advance the lower jaw" and thereby correct a Class II malocclusion by "jumping the bite". Kingsley was also acutely aware of the effect of the bite plate on bite depth. He observed that after the use of a maxillary plate the lower incisors "are no longer higher than the natural plane of the lower arch" and he made suggestions as to the possible causes
of this effect. Kingsley was also cautious not to extrude maxillary incisor teeth. He used elastics attached to a bite plate because, he said, "If moved back without the cutting edges being kept on the same plane, they would be likely to elongate enormously and give the child the appearance of a rodent."

There are many other scattered references to bite plates throughout the early literature. According to Kelsey (1938), when Baker introduced intermaxillary elastics at the turn of the century, the popularity of bite plates waned, but after Rogers delivered a paper in 1911, in which he suggested certain modifications and adaptations of the bite plate; and its use in the correction and retention of malocclusions, the bite plate again became established as a popular appliance.

Hawley introduced his retainer in 1919 and the subsequent modification by Atkinson (1937) brought about the evolution of the modern "Hawley bite plate".
Timing of Bite Plate Therapy
TIMING OF BITE PLATE THERAPY

The age at which bite plate therapy should commence may depend upon the aims of the treatment. McNamara (1973) found that the mandibular skeletal adaptation of rhesus monkeys to a type of maxillary splint, (that is, the alterations in the amount and/or direction of condylar growth), was evident in the younger age groups, but diminished in the adolescent and adult animals. On the other hand, there was more compensatory tooth movement in the older animals.

Deffez and Fellas (1977) have proposed that retromandibular occlusion be treated in the deciduous dentition, at approximately four years of age. The treatment, using a modified maxillary inclined plane to induce forward mandibular position, is completed when permanent incisors have erupted. Mew (1979) also considers that treatment directed at modifying mandibular position should commence early, although his contention is largely unsupported.

Bjork (1969) has advocated introduction of a bite plate in early childhood where pronounced forward mandibular rotation is suspected. Graber and Neumann (1977) point out that this developmental trend may persist from infancy until late adolescence. Bite plates, therefore, may also be useful in the later stages of growth.
Bench, Gugino and Hilgers (1978) have placed the correction of vertical problems high amongst their objectives of "early treatment". It is a major tenet of the Bioprogressive Therapy that the overbite is corrected before the overjet is corrected. They suggest that overclosure of the mandible with excessive freeway space will allow the condyle to seat distally in the glenoid fossa and cause detrimental mandibular growth responses. For this reason they state, "We consider anything which jeopardizes this upward, forward growth as a temporomandibular joint dysfunction and worthy of intervening treatment, regardless of the patient's age".

Pautola (1975) found in a study of the effect of bite plates in rats, that the younger the rat, the greater the reduction in overbite that occurred. Callaway (1940) and Moyers (1973) have said that bite plates work best during the mixed dentition stage, when premolars and second molar teeth are erupting, and there is rapid alveolar growth. Mathews (1959) while not disagreeing, points out that the requisite stage cannot be predicted for the individual patient. He therefore, advises the placement of a series of bite plates to be worn intermittently during the deciduous and mixed dentition years. Mathews' suggestion if followed, might, however, prolong treatment and tax cooperation.
Moyers (1973 P.690) has warned that bite plates should be used with extreme discretion in adult dentitions in which growth has ceased and the occlusal relationships have stabilised. Graber (1972 P.771), however, has said that in cases of overclosure bite plate therapy can accomplish stable bite opening even in a mature patient, albeit to a lesser degree and over a longer period of time.

On the question of the length of the period which a bite plate should be worn to achieve bite opening, Belger (1956) found little correlation between the period of bite plate use and overbite correction. However, Sleichter (1954) has reported that posterior dental vertical development diminishes as soon as molar contact is re-established, so for continuing elevation the bite platform may have to be constantly increased in height. Graber (1972 P.603) points out that the bite plate loses "efficiency" if not used during mastication. For adults, he suggests that the bite plate might be worn indefinitely at nights to serve as a "crutch" to prevent further deterioration of periodontal conditions, temporomandibular joint disturbances and bruxism.
Indications & Contraindications for Bite Plate Therapy
INDICATIONS FOR BITE PLATE THERAPY

In the following section attention will be centered mainly upon indications and contraindication to bite plate therapy, where effects upon jaw position have been suggested. Other indications will be either discussed briefly or only listed.

1. In the treatment of excessive overbite.

Salzmann (1979), in a research abstract, reviews the work of Fisk and McGraw, who studied the overbite changes associated with the interceptive orthodontic treatment of one hundred patients selected at random. Overbite changes were compared to a sample of untreated Burlington Research Centre controls who were crossmatched for age and sex. Statistically significant changes were found to be associated with the use of anterior bite plates and other "interceptive orthodontic treatment modalities". Cases which evidenced a deep overbite at the beginning of treatment showed a marked improvement after treatment.

2. In the treatment of excessive interocclusal clearance and overclosure:
Graber (1972 P.772) and Moyers (1973 P.586)

Graber (1972 P.772) stated that "Normally, there should be little or no change in lip contour between postural resting position and habitual occlusal position. A marked decrease in facial height and pursing of the lips on closure indicate lack of harmony of the two vertical
dimensions". (figure 3). To encourage eruption of posterior teeth in these cases of overclosure, Graber has advocated bite plate therapy.

Ross and Johnston (1972) have indicated bite plates for cleft lip and palate patients with similar vertical problems of what they have referred to as "excess freeway space".

3. In the treatment of extreme forward mandibular growth rotations, often associated with Class II, Division 2 malocclusions.

Bjork (1969) advocated introduction of a bite plate to counteract this tendency. During a forward mandibular rotation, the chin is directed anteriorly and upward. (figure 4). Supported by evidence derived from his longitudinal cephalometric metallic implant studies, Bjork (1969) has suggested seven criteria for distinguishing the forward rotation of the lower jaw. (Table 1). If on the basis of these criteria there is a suspicion of an extreme forward rotation bite plate therapy can be instigated with the object of encouraging increased posterior tooth eruption, and thereby transferring the centre of the mandibular rotation forward, or even turning the forward rotation into a backward rotation.

Callaway (1940) expressed the opinion that bite plates were indicated in the treatment of Class II, Division 2 malocclusions. He stated that "By removing the labial loop, the biting forces against the plane of the plate tend to drive the maxillary incisors labially, stimulate forward growth in the mandible and open the bite, all of which are necessary adjuncts to a correction in
FIGURE 3

Excessive overbite in an adult Class II malocclusion (top), and Class III malocclusion (bottom) Postural position is on the left and habitual occlusal position on the right. Note the marked decrease in facial height and pursing of the lips on closure.

(From Graber 1972 p 772).
FIGURE 4

A typical case of forward mandibular growth rotation
(From Bjork 1966 in Graber and Neumann 1977 P.166)
this type of case". Supportive evidence was not produced.

4. In the treatment of Class I and some Class II deciduous deep bite cases.

Mathews (1959) tested the hypothesis that "in Class I occlusions a close bite in the deciduous dentition imposes an arresting effect on the development of intercanine width necessary for the accommodation of the lower four permanent incisors". In other words bite plate therapy might "unlock" the mandible and allow it to reach its full growth potential. The excellent results reported by Mathews seem to be an indication for the early commencement of maxillary bite plane therapy in those four and five year old children exhibiting Class I and some Class II deep overbites.

Ricketts (1979) may have had Mathews's work in mind when, after describing the bite plate as "an ineffective type of appliance", he conceded that "there are cases in which a bite plate seems to assist in the development of occlusion and eruption of teeth".

Haynes (1979) described a case of severe deep overbite in which early bite plate and functional regulator treatment appears to have brought about marked improvements in the malocclusion and in the patient's facial appearance.

5. In the treatment of temporomandibular joint disturbance.

Rapid though perhaps temporary, pain relief following insertion of a bite plate, has been reported by Mathews (1967)
Moyers (1973 P.690) and other authors. Greene and Laskin (1972) however, concluded, from experiments using palatal plates with no occlusal coverage whatsoever, that psychological factors appear to play a very important part in relief of temporomandibular joint pain.

Kanter (1959), Posselt (1962), Mathews (1967), Zarb and Thompson (1970), Shore (1976) and others have suggested that the bite plate can be a valuable diagnostic aid in locating the "ideal" occlusal position by freeing cuspal interferences. Ramfjord and Ash (1971 P.244) have said that "changes in centric relation continue to occur until a relaxed stable terminal hinge position can be located...following the use of an acrylic bite plate". This statement has been corroborated by the findings of Williamson, Evans, Barton and Williams (1977).

6. In the treatment of bruxism.

Ramfjord and Ash (1971 P.245), Graber (1972 P.775), Moyers (1973 P.690), Graber and Neumann (1977 P.15) and others, have advocated the use of bite plates in the treatment of bruxism. Occlusal coverage eliminates cuspal interferences and Kanter (1959) states that removal of cuspal interferences reduces the extent of clenching and gnashing. He suggests that occlusal wear, clicking and muscle spasm will also be reduced.

7. In the treatment of crossbites or locked individual teeth.

Callaway (1940), Moyers (1973 P.690) and Salzmann (1974 P.296) have advocated the use of a bite plate
to remove occlusal interlocking while correcting crossbites, although McDonald and Avery (1978 P.429) and (Sim 1972 P.170) have expressed doubt as to its necessity.

8. **In the treatment of dual bite.**

Blumenthal (1940) has demonstrated a case of traumatic dual bite improved by the use of a bite plate and myofunctional therapy. Watson (1979) has also suggested the use of a bite plate to eliminate dual bites which he attributes to "muscle programming" sometimes present after orthodontic treatment.

9. **In the treatment of excessive curve of Spee.**

Sim (1972).

10. **In the treatment of periodontal disease.**

Glickman (1972 P.955 - 957).

11. **As an aid in myofunctional therapy.**

Hopkins (1940), Salzmann (1974 P.296).

12. **As a retainer.**

CONTRAINDICATIONS

1. Where bite opening by intrusion of incisors is required.

Moyers (1978 P.690) and Burstone (1977).

2. Where there is a tendency towards an anterior open bite.


3. Where there is a short lip length.

Burstone (1967) has warned that an increase in the vertical dimension could impair aesthetics and lip competence in patients with inadequate lip length.

4. Where a change in the interincisal angle is necessary.

Salzmann (1974 P.163) states that a change in the axial relations of the maxillary to mandibular incisors is not easily accomplished with bite plates, but this requirement is unnecessary where the bite plate is serving merely as an adjunct to treatment.

5. Where patient co-operation is lacking.
General Effects of Bite Plates
GENERAL OUTLINE OF BITE PLATE EFFECTS

Throughout the early dental literature, and even in more recent times, there has been an abundance of conjecture on the effects of bite plates on the dentofacial complex, but a dearth of scientific evidence on the subject. Any review of bite plate effects will therefore almost certainly suffer from this paucity of factual data.

For example:
Graber (1972 P.774) has suggested a number of applications and effects of bite plates:

1. Eliminating dominant posterior temporalis muscle activity with its attendant functional retrusion effects which at times may mean exacerbation of a Class II antero-posterior tendency.

2. Restoring stress to the mandibular incisors so that the force is transmitted primarily through the long axes of these teeth.

3. Stimulating eruption of posterior teeth and thus reducing the severe canine interference so often seen.
4. Preventing overclosure. Posterosuperior displacement or functional retrusion is frequently associated with excessive overbite. A bite plate constructed to prevent mandibular overclosure past the point of initial tooth contact will also eliminate the abnormal translatory condylar movement that may serve as a precursor of temporomandibular joint problems.

5. Preventing aberrations of the temporomandibular joint, and of tooth guidance.

6. Correction of abnormal overbite in younger patients.


8. Establishing the proper and most comfortable occlusal vertical dimension before the teeth are modified with permanent fixed restorations, in problems of full mouth reconstruction.

9. Where bruxism is present, a bite plate may show that excessive overbite is a causal factor, and its elimination may mean the cessation of the grinding and clenching that has plagued the patient for years.
Also Salzmann (1974 p.163) lists the changes that can be effected by means of the bite plate:

1. Forward positioning of the condylar head thus repositioning the mandible, especially in young children when growth is active.

2. Opening the bite and diminishing overjet of the anterior teeth.

3. Elevating the posterior teeth and/or slightly depressing anterior teeth.

4. Normalising the anteroposterior relationship of the occlusion.

5. Correcting the mesial position of the mandibular teeth in the deciduous dentition stage.

6. Increasing face height due mostly to vertical increase in the posterior dental region. Increase in vertical dimension is also accompanied by change in the mandibular position.

In the following sections, an attempt will be made to examine some of the bite plate effects more closely.
Effects on Incisor Height
BITE PLATE EFFECTS ON INCISOR HEIGHT

The use of a bite plate to bring about depression of the lower incisors has been both suggested and denied by various investigators.

Jackson (1922) and Mershon (1937) were of the opinion that supraclclusion of anterior teeth was always the cause of deep overbite. Mershon stated that "the only permanent change which can be brought about by the use of a bite plate is the depression of the anterior teeth into the alveoli". These claims, however, were based purely upon their proponents clinical experience and were unsupported by scientific data.

Wolfson (1938) agreed with Jackson and Mershon but did attempt to support his opinion with measurements taken from the dentofacial casts of four "non-growing patients" undergoing bite plate therapy. Callipers were opened to correspond with the distance from the bridge of the nose to the gingival border of upper central incisors before treatment. Without changing the callipers they were then applied to the cast of the finished case. This technique was repeated for the mandibular anterior teeth. Wolfson was able to show marked changes in the anterior overbite, and concluded that all the changes had occurred anteriorly.
However, as Wolfson gave no consideration to accelerated eruption of posterior teeth, to change in the mandibular position, or to any other effects that might also have explained the reduction in anterior overbite, his conclusion was spurious. Wolfson seems to have been strongly influenced by Mershon, to whom he refers as his friend and teacher, and he asserts that his findings simply confirmed what Mershon had known all along.

Hemley (1939) took an opposite point of view. He stated that "Depression of the lower incisor teeth as a result of using the bite plate was a rare occurrence and slight in extent". He even went on to cast doubt as to whether any other orthodontic procedure could depress lower incisor teeth. His studies were based upon measurements made directly on three hundred and twenty two patients treated with bite plates. He asserts that the increase in biting force on the lower incisors would strengthen the investing bone, rather than depress the teeth. He cites an histologic section as evidence to support his contention. Dense bone can be seen around three incisor teeth that were subjected to the influence of a bite plate for eleven weeks. However, for obvious reasons there is no pre-treatment histologic section, and so this precludes comparative assessment of bone density changes.
Hemley's method of assessment of change of incisor height is also open to criticism. Measurements were taken with sliding callipers positioned directly on patients. Such variables as soft tissue thickness and accurate positioning of calliper points, are not mentioned and yet would seem to be of importance when changes as small as fractions of a millimetre are being recorded. An example which amplifies this point is the measurement from the "incisal edge of the lower central incisor teeth to the inferior border of the mandible". Just how the point on the inferior border was standardised for the comparative measurements, is not stated. Nor is the problem of compression of soft tissues by the calliper points mentioned. Although these factors may have been taken into account by Hemley, they are not described and, therefore, doubt as to the conclusions drawn is engendered.

Callaway (1940), Haberle (1941), and Sved (1944) considered that lower incisor depression accounted for at least some proportion of the overbite correction, but again these were opinions given on clinical evidence alone, unsupported by any measurements.

Bahador and Higley (1944) conducted a "before and after" cephalometric study of twenty cases treated with Hawley bite plates over a period of from two to eight months. They considered that the majority of cases showed either no change
or some slight extrusion of the mandibular incisor teeth. Six cases, however, did show what appeared to be slight mandibular incisor depression, though this may also be interpreted as a reduced eruption rate.

Sleichter (1954) in a cephalometric study used a control group to correlate normal tooth eruption rates with those evident in patients undergoing bite plate therapy. He found no appreciable difference in the eruption rate of the maxillary incisors between the two groups. The mandibular incisor rate showed individual variations, but a mean decrease. Again, this need not indicate actual incisor depression, but merely a reduced eruption rate relative to total mandibular growth.

Belger (1956) and Broadway (1957) in separate studies found no significant depression of the lower incisor teeth and in some cases found a slight increase in height. Broadway suggested that perhaps a reflex muscular relaxation occurs when teeth contact the bite plate so that little, if any, depression of the lower incisors can eventuate.

The validity of this hypothesis is perhaps called into question by the experience of some patients wearing bite plates who complain of pain affecting the lower incisor supporting tissues.
Atherton (1963) examined twenty patients exhibiting deep anterior overbite. Cephalometric radiographs were taken prior to bite plate therapy and repeated when the bite had opened. Only three patients showed a decrease in the distance between the tip of the lower incisor and the lower border of the mandibular symphysis (fig.5).

![Figure 5: Illustrating the method of measuring lower incisor height.](image)

Atherton felt that the extent of depression in these cases was quite inadequate to account for the degree of bite opening produced. Most of the remaining patients showed no change at all in the height of the lower incisor, and six patients even demonstrated a further increase in height.

In a similar investigation of nine patients by Richardson and Adams (1963), the findings corresponded closely with the results obtained by Atherton (1963). Two patients showed slight depression of the lower incisors, whilst most showed
no change in the distance between menton and the incisal edge. In one patient, the lower incisor teeth continued to erupt slightly despite the bite plate.

Cousins, Brown and Harkness (1969) in a paper entitled "An investigation into the effect of the maxillary bite plate on the height of the lower incisor teeth", described a study of fourteen children in which an attempt was made to reduce some of the experimental variables in order to reach more reliable conclusions. Their sample consisted of seven boys and seven girls who were closely comparable in eruption status. The design of the appliance used was standardised, and very close limits were set for the duration of appliance treatment, the timing of the cephalometric records, and for the unit of measurement. The restriction of the investigation to a period of treatment of only two months limited the changes due to eruption of teeth and to growth of the maxilla and mandible.

Despite the strictly defined experimental parameters, no consistent result was shown. Ten cases, or seventy one percent, demonstrated a decrease in lower incisor height, while four cases, or twenty nine percent, exhibited either no change or showed an increase in height. Furthermore, the experiment confirmed that the level of change of lower incisor height was very small in proportion to the change in clinical overbite.
In nine of the fourteen cases it was 0.2 millimetres or less. Although statistical analysis found the error or their method to be insignificant, the authors acknowledge that their unit of measurement, 0.1 millimetres, is a particularly small dimension, and given the limitations of cephalometrics, it seems doubtful that changes of that order could confidently be reproduced.

Pautola (1972 and 1975 a, b), studied the effects of bite plates in animals. From the results of experiments carried out on dogs he concluded that lower incisor intrusion had occurred. This impression was largely deduced from the observation that "The third lower incisor was found to move vertically to the same horizontal level than (sic.) the first and second incisors". (fig.6)

Figure 6: Illustrating the vertical distance between the third lower incisor and the first and second lower incisors in dogs. (From Pautola, 1975a).
Normally the third lower incisor maintains a higher level. It seems just as likely, or perhaps even more likely, that the first and second incisors overerupted.

From the results of experiments using bite plates attached to the upper incisors of rats, Pautola concluded that the rate of incisor eruption had been retarded. Normally these teeth erupt 2.4 millimetres per week.

Since the morphology and physiology of rats and dogs differs so markedly from that of humans, the relevance of these results to man, is questionable.

Menezes (1975 a) conducted a cephalometric investigation of thirty seven children with Class II, Division I malocclusions, and compared them to a control group of twenty five children who were matched for age and sex, yet differed from the experimental group in that they had what was loosely described as "fairly normal occlusions".

In the short term, which Menezes defined only as the elapsed time between the insertion of the bite plate and bite opening, there was virtually no reduction in lower incisor height. In fact, some cases exhibited a slight increase in the height of the lower incisors but this result was not statistically significant.
Summary

It appears from the review of the literature that doubt still exists as to any active lower incisor depression occurring, although it seems plausible for retardation of the eruption rates of these teeth to occur.
Stability of Incisor Height Changes
STABILITY OF INCISOR HEIGHT CHANGES

Intrusion of incisors in order to correct overbite is considered undesirable at least by Schudy (1968) who has commented that "In treatment it (the mandibular incisor) can be intruded readily and has a strong tendency to extrude in the post-treatment period. For this reason it should never be intruded under any circumstances if it can be avoided".

The results of Menezes' (1975 a) "long term investigation" might corroborate Schudy's assertion. Over a mean interval of 22.8 months many cases showed an increase in lower incisor height. This could not be entirely accounted for by growth since, surprisingly, even when the experimental group was compared to the control group the differences in lower incisor height still remained, and were statistically significant in females. These findings suggest a tendency for incisors to overerupt after bite plate treatment. However, the differences in occlusion already mentioned between experimental and control groups, may account for this unexpected result.

Menezes (1975 b) also carried out a comparative analysis of the bite opening effects resulting from Begg multibanded treatment and bite plate therapy which he
found to be similar. Although in the Begg treated cases there had been an initial depression of lower incisors during stage one, by the end of treatment lower incisor height was found to have increased slightly.

Richardson and Adams (1963) noted that, in patients who showed a long term reduction in overbite, contact had been established between the incisal edges of the lower incisors and the cingulum area of the upper incisors.

Other authors including Popovich (1955) Schudy (1963 and 1968) Williams (1965) and Thurow (1966) have gone further by stressing the importance of a "correct" interincisal angle for stability of the corrected overbite. Schudy (1963) considers the ideal interincisal angle to be approximately one hundred and thirty five degrees.

There are limits to the amount of torque that can be applied using removable bite plate appliances. Fixed appliances have more versatility in this regard. Williams (1965) has spoken of the "unlimiting torquing potential" of the Begg technique.
It may be concluded that, where there is an obvious need to torque incisors, bite plate therapy can only be an adjunct to therapies involving more sophisticated appliances, whether these therapies are carried out simultaneously or subsequently.
Effects on Posterior Elevation
BITE PLATE EFFECTS ON POSTERIOR ELEVATION

Kingsley (1892), after observing the levelling effect of the bite plate upon the plane of occlusion, suggested elevation of the posterior teeth as one hypothesis to explain the effect.

Davenport (1905) agreed with this explanation, but Mershon (1937) disagreed, arguing that elevation of posterior teeth would require compensatory muscle lengthening, and that "Nothing known to science except accident, disease or surgery can increase the length of a muscle after it has reached the fullness of its growth". However, evidence of successful surgical corrections of skeletal dysplasias, the results of animal experiments (Sergi 1972), and observations of edentulous persons (Tallgren 1966), which indicate that muscles may have an ability to adapt to changes in the distance between their points of insertion, appear to contradict Mershon's opinion.

From an analysis of anthropometric measurements of three hundred and twenty two patients Hemley (1939) concluded that "growth in the molar region of the mandible was strikingly accelerated in the bite plate cases in contrast with the cases not treated orthodontically".
Although Hemley's method of assessment of change has been previously criticised as being inaccurate, the changes of one to four millimetres recorded in the posterior dental region were much greater than those recorded in the anterior region. The greater the order of change recorded, the less significant any error of recording becomes, and thus the greater the validity of the conclusions drawn.

Hemley (1938) also supported his argument that bite plates can facilitate the growth of bone in the posterior dental regions, by illustrating with dental casts the phenomenon of supraeruption; "we know that teeth, deprived of antagonists seek occlusal contact'. Moreover, when this occurs the teeth in question do not grow out of their adveoli, but the alveolar structure grows into the gap and carries the teeth along'.

Strang (1938), Hopkins (1940) and Callaway (1940) held that the main effect of the bite plate was to allow supraeruption of the posterior teeth. Haberle (1941) and Sved (1944) agreed, but believed that depression of the anterior teeth also occurred. These were, however, subjective clinical opinions without scientific evidence.
Bahador and Higley (1944) with the use of cephalometrics, were able to point to an increase in the posterior dental height in all cases; the maxillary teeth showing greater increase than the mandibular teeth. Sleichter (1954) later criticised this study on the basis that it lacked a control group. The criticism, however, does not seem justified. Twelve of the twenty cases were over fifteen years of age, ranging up to twenty six years of age. The entire treatment period was no more than eight months. In two patients aged ten and eleven years, the desired bite opening was obtained within two weeks. All of the younger patients Bahador and Higley explain, "were placed under observation for various periods of time to determine whether natural growth processes would open the bite. Only after such a period of observation had shown no apparent improvement was a bite plate placed in the mouth. The rapid improvement thereafter was convincing as to the stimulating effect of the appliance". Taking into account all of these factors, the observed phenomena could reasonably be accredited to the results of therapy, rather than to growth and eruption.

Sleichter (1954) concluded that the bite plate reduces anterior overbite by bringing about a marked increase in the eruptive rate of maxillary and mandibular molar teeth. He noted that this caused significant change in the occlusal plane, and also that the eruptive changes tended to return to normal rates as molar occlusion again became effective.
Belger (1956), Atherton (1963) and Richardson and Adams (1963) also found that the bite plate brought about accelerated eruption of the teeth in the buccal segments until these teeth were once again in occlusion. Belger noted that the upper molars were relatively less elevated than the other buccal teeth and suggested that the reason may have been the restraining effect of the molar clasps of the bite plates. Richardson and Adams explained that although they did not use a control group, "It would seem clear that the changes noted could not altogether be accounted for by growth as the period over which treatment was carried out was fairly short in most cases".

Parker (1964) did use an untreated control group and still found comparatively greater vertical increase in the posterior regions of the treated cases.

Sergl and Farmand (1975) inserted unilateral bite plates on the right mandibular teeth of eight young rabbits. After nine weeks all teeth were again in occlusion. To explain their observation, Sergl and Farmand postulated that the eruption of the stressed teeth was inhibited, while there was accelerated eruption of the relieved contralateral teeth.
Menezes (1975, a) found increased molar height in the group treated with bite plates as compared to the untreated control group.

SUMMARY

Most researchers have found that the change in anterior overbite observed in patients undergoing bite plate therapy is associated with an elevation of teeth in the buccal segments.
Stability of Posterior Elevation & Considerations of Freeway Space
STABILITY OF POSTERIOR ELEVATION AND CONSIDERATIONS
OF FREEWAY SPACE

A number of researchers have postulated that an increased vertical dimension resulting from bite plate therapy encroaches upon the freeway space and therefore, cannot be stable because of limitations imposed by the musculature.

Mershon (1937) was emphatic that "stretched" muscles drive molars and premolars back into the aveoli. Hemley (1938), too, accepted the concept of muscle dominance over bone, but with reservations. He suggested that muscle hypertonicity, a symptom of disorders of the metabolism, was responsible for reduced alveolar growth. Bite plates might control the excess muscle forces generated, and allow new bone growth to occur. This growth could be sustained by maintained use of the bite plate until maturity, when the muscle hypertonicity usually disappeared.

Broadway (1957) also believed that relapse occurred if the bite was opened beyond the normal rest position of the mandible.

Anderson and Picton (1958) demonstrated a twofold increase in occlusal force following bite raising with occlusal onlays. They noted that generalised contact was rapidly
re-established, though they were uncertain as to whether
this was due to intrusion of the capped teeth, or eruption
of the other teeth or both.

Ramfjord and Ash (1966 p.15) warned of the futility of allowing,
by orthodontic or prosthetic means, encroachment by buccal
segments on the musculature. They believe that relapse
will occur when such teeth subsequently become intruded and
normal freeway space is regained.

Thompson and Brodie (1942) considered that most cases of
deep anterior overbite had a normal rest position, but an
excessive freeway space. Buccal teeth could be elevated,
provided an adequate interocclusal space remained and the
mandible was not forced to a position beyond that of
physiologic rest.

Sleichter (1954) makes the interesting point that,
"...it is difficult to understand why normal eruption does
not take advantage of this space if it is actually an excess".
Sleichter believed that however large, the freeway space was
often normal for the individual and that any attempt to reduce
this space would eventually be followed by relapse.
Graber (1972 P.771) has suggested that bite plates can stimulate an increase in the occlusal vertical dimension in patients evidencing excessive interocclusal clearance and overclosure.

Duckmanton's cephalometric study (1964 and 1965) reaffirmed the traditional concept of a stable, innate and unalterable rest position of the mandible. (Thompson and Brodie 1942). According to this theory the space between the jaws is determined by the resting lengths of the mandibular muscles. Tooth eruption into this space ceases before contact of the occlusal surfaces occurs, thus leaving a gap of two to three millimetres, referred to as the freeway space. It follows therefore, that the distance between the jaws when the teeth are together (the occlusal vertical dimension) is a little less than the space between the jaws when the mandible is in the rest position (rest vertical dimension).

According to Nairn (1976), Moller (1976), Yemm (1976) and Dibdin and Griffiths (1976), the concept of a fixed mandibular resting posture is an oversimplification, the rest position being influenced by many factors. In the short term, fatigue, posture, psychological state and intra oral pressure can change the resting interocclusal distance. This is in addition to long term effects resulting from removal of occlusal contacts and ageing.
Dibdin and Griffiths (1976) reached this conclusion by monitoring the resting posture of the mandible using methods employing radio telemetry. They also looked into the effect of attaching a bite plate to the dentition and found rapid adaptation to the appliance with a corresponding increase in interocclusal distance and minimal increase in the number of occlusal contacts. Unfortunately this line of their investigation was only pursued for one subject, perhaps because of the difficulty in finding people with fairly complete dentitions, but with a posterior extraction site large enough to accommodate a small intraoral transmitter.

Nairn (1976) found that he could not accept the traditional concept of a stable rest position because it was at variance with a number of observations. For instance, patients fitted with immediate dentures constructed to reproduce the occlusal vertical dimension provided by the natural teeth often returned with symptoms associated with wearing dentures made with too great an occlusal vertical dimension. This implies that the vertical dimension provided by the natural teeth is not necessarily that required in dentures.

On the basis of this and other observations, Nairn offered the conjectural explanation that the rest position of the mandible is not stable, but is a position taken up in response to circumstances, such as the size of the lips, the length of the muscles, the size and posture of the tongue, the
tendency of the soft tissues to return to a state of rest, and in particular, the amount the teeth have erupted.

One of Moller's (1976) observations seems to support Nairn's hypothesis that mandibular position is responsive to circumstances. Apparently subjects with unilateral crossbite may also have postural asymmetry, which can be demonstrated with electromyography. We would expect mandibular displacement with teeth in the intercuspal position, but without tooth contact it is surprising to see an influence on mandibular postural activity.

On the basis of electromyographic studies Yemm (1976) concluded that the physical properties of the tissues enveloping the mandible are likely to be responsible for the rest position and that contraction of the jaw muscles is not a major factor.

One of Nairn's statements seems to sum up some of the implications of recent research. He said "I think it apparent that not only is the freeway space irrelevant, but that the rest position of the mandible is very much a red herring, both in dentures and in consideration of the natural dentition".
Ricketts (1979) admits to not being greatly influenced by considerations of freeway space except in temporomandibular joint dysfunction cases.

The implications of the challenge to the concept of an innate and unalterable mandibular rest position may explain why some of the patients treated with bite plates by Bahador and Higley (1944) and Belger (1956) still maintained an improved overbite relation thirteen months out of retention, although it is also possible, that treatment effects may not have brought about encroachment upon the freeway space. Of nine patients treatment by Richardson and Adams (1963), six had overbites that were appreciably less, twelve to twenty five months after bite plate treatment, than they had been before treatment.

Since there has been little research on the stability of increased molar height following bite plate therapy, some of the work of those who have examined molar elevation following fixed appliance therapy will be discussed instead.

Schudy (1968), like Ricketts, disregards considerations of freeway space. He sees the aesthetics of the individual as being the main limiting factor to
increased posterior vertical development. He chastises the many authors who in his opinion express concepts which are "wholly untrue and diametrically opposite to the facts". He is referring to the often-quoted belief that muscle force will intrude molars which have been moved occlusally during orthodontic treatment. In fact Schudy (1965) advocates treatment, in many cases, be directed towards elevating mandibular molars. "Molars almost never are intruded into the bone subsequent to treatment. Thus, if the molars can be induced to move occlusally, they will remain at that level in almost all instances". These assertions, however, suffer from a lack of supporting evidence.

Costello (1968) after reviewing the conflicting opinions regarding the stability of increased molar height states, "The truth can only be determined by further longitudinal cephalometric studies of treated cases, during treatment, and many years out of retention".

Such a study was undertaken by Thompson (1979). He investigated the stability of the changes in overbite and occlusal plane produced as a result of molar elevation and incisor depression during Begg treatment. Cephalograms were measured before treatment, after treatment, and after
all retention. The post retention settling period ranged from seven months to seventy seven months.

Thompson found that the treatment mechanics tended to depress the lower incisors 1.4 mm on average, and elevate the lower molar 3.5 mm on average. During post-treatment settling, the lower incisors tended to return to the pretreatment level, but lower molar elevation not only remained stable, but in fact continued vertical growth of approximately 0.9 millimetres. Although Thompson's results seem to support Schudy's view that molars do not become "de-elevated" once induced to move occlusally, the method of assessment of molar elevation does not take into account the mesial movement of molars during treatment. Costello (1968) has pointed out that teeth moved into a region of greater interdental space falsely give the impression of having been elevated.

SUMMARY

In summary it appears that agreement amongst researchers is still lacking as to the stability of increased molar height occurring in response to treatment. However, there is increasing evidence suggesting that the orofacial tissues are more adaptable than was formerly believed. In particular the concept of a stable, innate and unchangeable mandibular rest position is being challenged.
Skeletal & Muscular Effects
SKELETAL AND MUSCULAR EFFECTS OF BITE PLATES

Very little consideration appears to have been given to bite plate effects more remote than the immediate dentoalveolar processes, although Rogers (1935) Mershon (1937), Breitner (1940), Sved (1944) and Salzmann (1974 P.163) have suggested that such changes occur.

Breitner (1940) (1941) conducted histologic studies on the tissues of Macacus rhesus monkeys. He observed that "raising the bite in the incisal region, as effected by the use of the commonly known bite plane, produced extra-alveolar bone changes, namely: shallowing of the glenoid fossa, bone deposition on the posterior side of the ramus from the condyle down to the region near the mandibular angle, and bone resorption on the anterior side of the condyle and at the lower border of the mandible and mandibular angle". (Fig. 7)

In the discussion that followed Breitner's paper, Riesner (1940) stated that he had corroborated Breitner's histologic findings, by roentgenographically recording similar changes in the glenoid fossa, the head of the condyle and in the angle of the jaw.
FIGURE 7

Extra-alveolar bone changes following the use of a bite plate for five weeks in Macacus rhesus monkeys.

(From Breitner 1941).
More recently, in McNamara's longitudinal electromyographic, roentgencephalometric, and histologic studies, a maxillary splint, displacing the mandible two millimetres downward and two millimetres forward, was found to change the behaviour of the orofacial muscles in young monkeys. Skeletal adaptations throughout the craniofacial complex, followed by a progressive disappearance of the modified neuromuscular pattern, was observed.

Sergl and Farmand's (1975) study, using unilateral bite plates in young rabbits, provided a method of investigating comparative functional adjustments. After nine weeks the animals were killed, the soft tissues removed from the carcasses, and the skulls were photographed and radiographed. Then the mandibles were sectioned sagitally and tracings of the two halves were superimposed.

Asymmetric skeletal changes in the ascending ramus, body of the mandible and condyle were observed. Preparations made from the control group were symmetric in comparison. Sergl and Farmand attempted to explain their findings by suggesting that disproportionate stretch of the masticatory muscles resulted in a change in the pattern of bone growth. For instance the condyle on the relieved side was the site of more bone growth and the muscle insertion sites had less bone growth until equilibrium was reached.
Mew (1979) has argued that relatively large orthopaedic changes are possible in animals, so that it should also be possible to mimic these changes in children to their advantage. He has presented case reports which appear to show skeletal changes induced by a series of simple appliances. Mew has referred to this treatment as "bioblock therapy".

Deffez and Fellus (1979) using a modified maxillary inclined plane, and Haynes (1979) initially using a bite plate and then a "functional regulator, have been able to achieve marked improvements in the mandibular posture of their young patients.

SUMMARY

Clinical and experimental evidence appear to indicate that structural modifications to the temporomandibular fossa, the condyle, mandibular and maxillary basal bones, and other areas, do occur although the complexity of the neuromuscular and skeletal adaptation to altered orofacial function as shown by McNamara (1973) discourages premature practical conclusions.
Stability of Skeletal & Muscular Effects
STABILITY OF SKELETAL AND MUSCULAR EFFECTS

There has been little research of the post-treatment stability of skeletal and muscular changes. Most investigators merely speculate as to the stability of observed morphologic adaptations.

Riesner (1938) believed that many of the changes induced by bite plates were pathologic and therefore unstable. He recorded radiographically what he described as a destructive reaction at the posterior surface of the articular eminence and at the anterior margin of the condylar head.

Breitner (1940), perhaps influenced by Mershon (1937), felt that artificially elongated muscles tend to re-establish their original length, but in so doing might permanently change the morphology and position of the mandible.

The question of whether muscles have the ability to adapt to an altered local environment seems central to the issue of post-treatment stability. McNamara (1973) and Goldspink (1976), amongst others, have addressed themselves to this question.
McNamara (1973) has listed possible mechanisms of neuromuscular adaptation:
1. Elongation of the muscle fibres themselves.
2. Establishment of altered neuromuscular feedback mechanisms.
3. Migration of muscle attachments along bony surfaces.
4. A change in muscular dimensions due to displacement and rotation of the bony elements.

Goldspink (1976) has examined the first of the above listed mechanisms and on the basis of experimental studies came to the conclusion that striated muscle is a very adaptable tissue and able to adjust its sarcomere number, and hence its fibre length, to the functional length of a muscle.

McNamara (1973) has investigated the last of the above mechanisms. Although no direct cause-and-effect relationship was established between muscle function and bone remodelling, a general sequence of adaptations was postulated. First, proprioceptive stimuli from the orofacial area were altered by the introduction of the appliance. Existent functional patterns were interrupted and re-organised. This in turn, caused a change in maxillomandibular functional relationships. This change in functional pattern altered the orofacial environment in such a way that tissue structural adaptations
resulted and an anatomic balance was eventually restored. As this occurred, neuromuscular compensation correspondingly declined and functionally more efficient patterns were developed. In summary, McNamara observed a skeletal adaptation to the experimental conditions, followed by a progressive disappearance of the modified neuromuscular pattern.

If one is able to accept that muscles can adapt to altered skeletal morphology, which then results in a new state of balance between muscle and bone; then one might also accept the corollary that a permanent retention of the improvements achieved in occlusion and craniofacial pattern, is possible. The fact that it is extremely difficult to force the mandible to bite further back after being transferred anteriorly by activator wear, (Graber and Neumann 1977 P.157) lends support to this hypothesis.

In the final analysis the stability of structural modifications requires far more study. However, it would seem to depend on a multiplicity of factors in each individual. Morphogenetic pattern, age, sex, functional pattern, appliance control, orofacial habits and other factors may be involved.
Effects on Mandibular Rotation
BITE PLATE EFFECTS ON MANDIBULAR ROTATION

One would expect a change in the mandibular plane angle to occur as a secondary effect of bite plate therapy, since if there was elevation of molars, these teeth could act as pivots around which the mandible might rotate.

Ricketts (1979) appears to hold this view. He said, "Autorotation can be caused by bite opening or by extrusion of teeth from the pull of intermaxillary elastics or the levelling of the curve of Spee. Both procedures rotate the mandible backward, due to the fact that the mandible is held open by extrusion of teeth and against the pull of the muscles". This is, however, an empirical deduction only.

An increase in facial height, produced by increasing the angle which the mandible bears to the maxilla or to the sella-nasion plane, has been observed by Bahador and Higley (1944), Atherton (1963), and Richardson and Adams (1963).

Eighteen of the twenty cases studied, by Atherton (1963) evidenced an increase in the mandibular plane angle. Of the two remaining cases, one showed no change in this angle, while the other demonstrated a one half degree reduction. In six patients, the increase was less than
one degree. To Atherton, this was enigmatic. Two millimetres or more of bite opening was produced in all his cases. He had reasoned that, if it is assumed that the bite is opened by accelerated eruption of the buccal segments alone, then for each one and a half millimetres of bite opening, the change in the mandibular plane angle ought to be approximately one degree. Since the bite was opened by two or more millimetres, the expected angular change ought to have been at least one degree, but it was less than this in eight of the twenty cases. Atherton postulated that condylar growth accounted for this discrepancy between the expected and the actual opening of the mandibular plane angle.

Richardson and Adams (1963) also found an increase in the mandibular plane angle in most of their patients where a long term reduction in overbite had been achieved. Like Atherton, they too were puzzled when the expected correlation between anterior overbite and the cant of the mandibular plane was not evident. They wrote, "...contradiction and paradox are not entirely absent, as in one case in which the overbite is reduced, the angle between N-S and the mandibular plane is actually less than it was before treatment".
Bjork's work (1969) may explain this observation. He has shown that during growth, the mandible may rotate principally in one of two different directions. He has described an anterior and a posterior rotation (fig.8). In those cases that puzzled Atherton, and Richardson and Adams, a forward growth rotation of the mandible might have masked the backward rotation induced by the bite plate.

Schudy (1964 and 1968) pointed out that posterior height changes result in significant anteroposterior dental and profile changes. He took cephalograms of an edentulous and presumably mature individual, progressively building up the denture molar height between exposures. He was able to show that as the posterior vertical dimension increased, the chin swings downward and backward, and the mandibular plane becomes steeper. He concluded, therefore, "that molar height not only controls the vertical position of the chin, but also to a considerable extent the anteroposterior position". Whether it is valid to extrapolate Schudy's conclusions derived from observations of an edentulous, non-growing individual, and apply them to a complex, growing, adaptable, individual undergoing treatment, is arguable. Remodelling and repositioning changes of the jaws are just two of the complicating factors which should also be considered.
FIGURE 8

One case of backward mandibular growth rotation (left) and one case of forward mandibular growth rotation (right) (From Bjork 1969).
Lavergne and Gasson (1976) have suggested that a knowledge of the pattern of mandibular growth rotation is of importance when planning treatment based upon growth evaluation. It is also of special value in identifying the possibilities of influencing mandibular rotation during treatment.

Since bite plates seem to have the capacity to influence mandibular growth rotation, it is worthwhile reviewing some of the studies of jaw rotations.

Both Odegaard (1970), and Lavergne and Gasson (1976) have used metal implants to assist them in evaluating the degree of rotation in relation to other variables in the facial skeleton. Odegaard found that the magnitude of rotation seemed unrelated to the degree of facial prognathism or to the inclination of the mandibular plane. Nevertheless, Odegaard did show that, when treatment extrudes molars, there is a decrease in the degree of anterior rotation. Molar extrusion was also suggested by Lavergne and Gasson (1976) as the means by which an orthodontist might influence the degree of mandibular rotation.

Isaacson, Isaacson, Speidel and Worms (1971) studied skeletal and dental parameters in patients exhibiting extreme variations in the mandibular plane angle. The study
emphasized the relationship between the magnitude of the angle and the orthodontic management of the case. Thus they advocated different mechanics for different facial types.

Menezes (1975a) found both a short and a long term increase in the mandibular plane angle following bite plate therapy. At the same time a control group showed a reduction in this angle.

The work of Lulla and Gianelly (1976) challenged some of the previous notions about the diagnostic value of the mandibular plane angle. For example Schudy's (1968) paper indicated that correction of overbite is difficult in low angle cases and it is also difficult to hold the correction, but in steep angle cases overbite corrects readily and is easy to hold. For these reasons diagnostic criteria (Ackerman and Proffit 1969, Williams 1970), and treatment procedures (Schudy 1968, Williams 1970), have been directed specifically towards taking account of the slope of the mandibular plane.

Lulla and Gianelly's study of forty seven patients focused on the relationship between the mandibular plane angle at the start of treatment, and the clockwise rotation of the
mandible and overbite changes that occurred during the bite opening phase of treatment.

Correlation coefficients were computed, and statistically significant but weak correlations were found, which indicated that pogonion was on average more retrognathically placed in patients with steeper mandibular plane angles. However, at least within the confines of their study, the association was not particularly striking. They concluded that "...the cant of the mandibular plane or the changes that occur in its slope are apparently not good parameters with which to predict the position of pogonion and the success of bite opening in most instances".

In recent years Isaacson, Zapfel, Worms, Bevis and Speidel (1977) and Isaacson, Zapfel, Worms and Erdman (1977) have reaffirmed the view that changes in posterior height result in significant anteroposterior dental and profile changes. They deduced that, in order for mandibular rotation to occur, there must be disproportionate vertical growth at the condyles and fossa compared to the sum of vertical growth at the maxillary sutures and the maxillary and mandibular alveolar processes. They have suggested a method of determining the centre of the mandibular rotation using geometric principles. Moyers and Bookstein (1979) have
been critical of the technique claiming that the centre of rotation derived in this way is wholly an artifact of the registration procedure since all parts of the face, not just one, are changing with growth. This criticism may be inapplicable if rotation has been induced by treatment, not growth, over a short period of time.

The spatial position of the centre of rotation in terms of its vertical and anteroposterior location has implications in treatment upon the profile, particularly the position of pogonion, and upon the occlusal changes, such as overbite correction. It is useful to be able to predict the type or pattern of growth rotation and then to plan treatment, utilising extrusive or intrusive posterior forces specifically for that type of facial pattern.

SUMMARY

In a number of studies bite plates have been shown to effect changes in the mandibular plane angle

Some authors have suggested that orthodontists might influence the degree of jaw rotation and thereby, perhaps, bring about anteroposterior dental and profile changes.

Other authors have either been unable to find a correlation, or have found only weak correlation, between mandibular rotation and facial prognathism.
Stability of Mandibular Rotation
STABILITY OF MANDIBULAR ROTATION

Although Atherton (1963) postulated that eventually mandibular growth in a downward and forward direction would return the maxillo-mandibular angle to its pretreatment value, the stability of any mandibular rotation brought about by bite plate therapy, has not been examined. Therefore the stability of this effect that might be produced by fixed appliance is discussed instead. It should be borne in mind however, that perhaps the different appliances produce different effects with consequently different sequels.

Schudy (1968) considers an increase in the mandibular plane angle to be permanent. Williams (1970), on the other hand, is inclined to a different view. He has spoken of the changes in the mandibular plane angle both during and after bite opening with Begg mechanics. His basic premise is that treatment has only transient influence upon the inclination of the mandibular plane, and that if there is a growth period following treatment, the genetic growth pattern will reassert itself. Generally this growth pattern in humans is manifested by a flattening of the mandibular plane, the mandible thus becoming more prognathic.
Williams has observed that at the start of Begg treatment, Class II mechanics brings about rapid elevation of the lower molars which creates an immediate and complimentary steepening of the mandibular plane angle.

After treatment, the mandibular plane reverts back to its original inclination. The degree of this flattening process is related to the growth trend exhibited by the patient prior to treatment.

Williams described five differing situations:
1. If serial pretreatment cephalographs indicate that the mandibular plane angle was essentially stable, it can be expected that it will revert only to its pretreatment inclination.

2. If the mandibular plane angle was decreasing prior to treatment, Williams says we can expect the inclination will close beyond its original inclination, depending upon the magnitude and duration of the post-treatment growth process.

3. If the inclination of the mandibular plane was increasing prior to treatment, which Williams says is "rare and opposite to the general nature of facial growth trends," then this increase may continue after treatment.
4. If treatment is undertaken after growth is completed, then any mandibular opening is minimal and invariably recovers if it does occur.

5. Only in cases exhibiting mouth breathing or other respiratory conditions, where the mandible is held in an open position in excess of the freeway space, is there the potential for a permanent opening of the mandibular plane angle, contrary to the genetic pattern.

Williams and Hosilla (1976) backed up his assertions with a cephalometric appraisal of two hundred and sixty treated cases. In this study it was found that the mandibular plane angle "more than recovered its original inclination after treatment".

It is interesting that no corollary has been drawn to suggest that as the mandibular plane flattens, the bite depth increases.

Lavergne and Gasson's study (1976) of the annual variations in the degree of mandibular rotation, indicated that the rotation of the mandible during growth was a complex phenomenon changing periodically in direction and intensity.
This suggests that Williams' views on mandibular pretreatment growth trends are too simplistic to be of much use in predicting post-treatment mandibular plane changes.

**SUMMARY**

It appears that during normal growth most people exhibit an anterior rotation of the mandible.

It is still difficult to predict accurately the permanence of changes in the mandibular plane angle occurring as a result of treatment.

The relationship, if any, between change in overbite, and change in mandibular plane angle is difficult to define.

There does appear to be some correlation between change in the inclination of the mandibular plane after treatment, and the duration, amount, intensity and direction of mandibular growth remaining post-treatment. The corollary of the connection is that if one is aiming at a permanent change in mandibular plane angle, the therapy that induced the change should be continued until growth is complete. As was previously mentioned, Graber and Neuman (1977 P.164) have made this point in reference to the use of bite plates, in cases of extreme forward mandibular rotation.
Aims
AIMS OF THE INVESTIGATION

To test, using roentgencephalometric methods, the effects of the Sved bite plate upon the mandible. Specifically this was done by evaluating possible change in:

1. the mandibular plane angle
2. the incisor overbite
3. the anterior facial height
4. the chin point
5. the lower incisor inclination.

To test the hypothesis that as bite opening occurs with the Sved bite plate, there is a hinge opening rotation of the mandible.
Materials
MATERIAL

The sample for this study consisted of nine boys and seven girls who were referred by their dentists to a Sydney orthodontic practice for treatment of their malocclusions. A tenth boy failed to report the loss of his appliance for over four weeks, and so was excluded from the sample.

Race. All of the children were Caucasian except for one Chinese girl (E.K.)

Age. (Table II) The ages of the children at the start of treatment ranged from 11 years 6 months to 15 years 6 months for the boys, and from 10 years 6 months to 15 years for the girls. The average age for both sexes was 12 years 10 months.

CRITERIA FOR SELECTION. All of the patients comprising the sample were diagnosed as having deep overbites by an experienced orthodontist without any knowledge that the patients were to become the sample group for this investigation. The diagnosis and subsequent decision to commence treatment with a maxillary bite plate, were made on the basis of a total assessment of each patient's clinical, intraoral examination, and records, including maxillary and mandibular dental casts, trimmed in centric occlusion, frontal and profile facial photographs, and a cephalometric analysis (combination of Steiner and Downs). Apart from the fact that all of the patients in the sample had deep overbites, they evidenced a variety of malocclusions, and mandibular plane angles (Table V)
and could be considered fairly representative of the range of patients seen in orthodontic practice.

**CONTROL GROUP.** For a controlled study it would be desirable to have matched pairs in terms of age, sex, growth status, and malocclusion. But this would necessitate procuring young patients with deep overbites, withholding treatment, and yet taking cephalometric x-rays four months apart. Such a course of action could not be justified on moral or ethical grounds. However, for two main reasons, it was felt that a control group was probably unnecessary in this investigation.

1. The first reason is related to the short term nature of the study. The average time period between the pre-treatment and the post-treatment cephalographs was only 3.9 months. Growth changes over this period would probably be small. In any investigation, the shorter the period of treatment, the greater will be the proportion of change due to that treatment.

2. The second reason is that the angular and linear changes being recorded over the short time span were relatively large, and highly significant.

Nevertheless, the control group used by Menezes (1975 a) and the group used by Corelius and Linder-Aronson (1976) to some extent serve the purpose of this investigation also. Menezes' control group consisted of twenty five children (seventeen boys and eight girls). They ranged in age from nine to thirteen years with an average age of ten years seven months. They were
described as having fairly normal occlusions, which appears to make them inappropriate as a control group. The difficulty, as Menezes explained, is withholding treatment from a group that do have malocclusions. However, Menezes found that the differences between his experimental and control groups "...were not relevant to the differences which were found as a result of (bite plate) treatment". Two lateral cephalographs were taken of the control group nineteen months apart.

Corelius and Linder-Aronson (1976) studied a group of thirty children (twenty boys and ten girls), who evidenced a variety of occlusions. They ranged in age from seven to twelve years. Cephalographs were taken three to four years apart.

**DESIGN OF THE BITE PLATE**

Sved bite plates (figure 9) were made for each patient with the bite platform parallel to the occlusal plane, as observed from the study models, and with the platform height just slightly below the incisal edges of the maxillary anterior teeth. (figure 10). As Mathews (1959) had already found, it appeared legitimate to ignore the freeway space since the children uniformly tolerated whatever degree of opening was incorporated in the plate.

To improve the aesthetics, the Sved plates were made of clear acrylic resin. They were constructed using a flask, heat curing method since a strong acrylic is needed to minimise the effect of the mandibular
FIGURE 9

The Sved bite plate as worn by the patients of this investigation.
FIGURE 10

A schematic profile drawing of the Sved bite plate illustrating the palatal plateau extended over the incisal edge, and the impact of the mandibular incisor against the flat surface.
anterior teeth wearing grooves into the platform. Deep grooves might prevent the mandible adopting a new posture relative to the maxilla, and might also prevent the occurrence of any change in lower incisor inclination.

Extending the plateau of acrylic over the incisal edges of the maxillary anterior teeth (figure 10) provided ample retention, thus avoiding the necessity of clasps on the maxillary posterior teeth and potential impediment to their eruption.

The patients were instructed to wear their appliances at all times, including meals, with the exception of removal for cleaning and oral hygiene.

CEPHALOMETRIC RECORD

Two lateral cephalometric radiographs were taken for each patient, the first during the initial examination, though in most cases it was some months before bite plate therapy commenced (Table II), and the second when a significant reduction in the depth of overbite was clinically obvious (Table II).

The patients were seen at intervals of approximately four weeks. In two cases the final cephalograph was taken at the first recall appointment, the depth of overbite already appearing to be appreciably diminished. A reduction of four millimetres or more was later confirmed cephalometrically.
Average time between cephalographs was 3.9 months.
Average treatment time was 2.4 months.

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6. the elapsed time between the 1st and final cephalometric records.
5. the total elapsed treatment time,
4. the age when the final cephalometric record was taken,
3. the age when the study plate was issued,
2. the age when the initial cephalometric record was taken,
1. Patient’s sex.

TABLE II

SHOWING
The Reliability of Cephalometric Measurements
THE RELIABILITY OF CEPHALOMETRIC MEASUREMENTS.

Included in the extensive literature on cephalometric methods are many papers dealing with sources of error in the method. Baumrind and Frantz (1971 a and b) have identified three general types of error in head film measurements. These are:

1. Errors of projection
2. Errors of landmark identification
3. Mechanical errors of tracing and measuring.

More recently Moyers and Bookstein (1979) have suggested that conventional cephalometrics has conceptual as well as technical handicaps. Thus we can add to the above list:

4. Errors due to the inappropriateness of conventional cephalometrics to the living skull.

1. ERRORS OF PROJECTION

When a three dimensional, highly irregular object, such as the skull, is radiographed, there is always some degree of enlargement and distortion in the resulting two dimensional image. In discussing this problem Thurow (1951) recommended making the enlargements constant in every film, while
Broadbent Sr., Broadbent Jr., and Golden (1975) further suggested calculating the enlargement factor for each film. Vogel (1967) too, has suggested introducing correction factors but these methods are cumbersome and time-consuming, making them difficult to apply in daily practice.

In theory, points that lie in the midsagittal plane are held at a constant distance from both the film and the x-ray emitter by the nature of the cephalostat design. Hence, these points all have a similar enlargement factor. Steiner (1953), however, has pointed out the difficulty of precise repositioning of patients in relation to the ear-rods, so that only rarely does the true anatomic midsagittal plane coincide with the midsagittal plane of the cephalostat. Baumrind and Frantz (1971, b) rejected the argument of authors who had contended that rotation of the skull in the cephalostat of less than ten degrees was unimportant. They felt that this was merely a statement about the imprecision of the technique, since some alteration in the projection of angular and linear relationships must occur with any rotation of the skull whatsoever. Bjork (1947) suggested that the difference in images occurring due to the slight rotation of the head could be corrected by taking mid-points between images of the left and right sides, but Salzmann (1966, p. 502) disagreed on the grounds that the face is asymmetrical.
Not only should the x-ray beam pass at right angles to the midsagittal plane, but the principal axis should pass through the transporion axis. Baumrind and Frantz (1971, b) have pointed out that because x-rays originate from a small focal source and are not parallel, there must always be a degree of distortion and enlargement. The enlargement factor varies with the plane in which the anatomic landmark being traced, lies. The distortion is due to foreshortening of distances between points lying in different planes and radical displacement of all points and structures not on the principal axis.

An attempt is conventionally made to reduce the significance of projection errors, at least in part, by the use of angular rather than linear measures wherever feasible. This is effective because values of angular measures remain constant, regardless of enlargement factors. In addition, the linear measures used are between points that lie in the midsagittal plane.

2. ERRORS OF LANDMARK IDENTIFICATION

The apparently straight forward process of identifying specific anatomic landmarks on head films is one of the most important sources of error in cephalometry. (Bjork 1947), (Graber 1954), (Richardson 1966) and (Baumrind and Frantz 1971, a).
Some landmarks are more prone to errors of reproduction than others. This is mainly due to:

i. Superimposition of anatomic detail; for example, the Bolton point. (Baumrind and Frantz 1971, a, b). and (Graber 1954).

ii. The difficulty of identifying landmarks that are placed on curves with wide radii; for example point A and point B. (Baumrind and Frantz 1971, a, b) and (Moyers and Bookstein 1979).

iii. Movement during exposure causing blurring of the image.

iv. Lack of film contrast, and presence of emulsion grain. (Gravely and Benzies 1974).

There are other landmarks that are comparatively easier to identify. For instance, those landmarks that are located on the outlines of the cranium have a sharpness in contrast to the roentgenogram, making accurate reproduction easier to attain.

Landmark identification can also be affected by individual variation in skeletal morphology and by changes associated with growth. (Moyers and Bookstein 1979).
Baumrind and Frantz (1971, b) have suggested steps that can be taken to reduce errors in landmark identification. These are:

i. More rigorous and uniform definition of landmarks.

ii. Abandonment or reduction of reliance on those landmarks or measures which cannot be defined rigorously enough to make them reproducible with acceptable reliability.

iii. Routine use of replicated measurements. This can be done efficiently by making appropriate use of computer technology.

3. MECHANICAL ERRORS OF TRACING AND MEASURING

The errors introduced in drawing lines between points by hand and in measuring with ruler and protractor are very real but are conceptually trivial. Baumrind and Frantz (1971, b) have suggested that these mechanical errors can be entirely eliminated by delegating to computers (with digitizers) the task of calculating linear and angular relationships between given landmark co-ordinates.

4: ERRORS DUE TO INAPPROPRIATENESS OF CONVENTIONAL CEPHALOMETRICS TO THE LIVING SKULL.

Moyers and Bookstein (1979) have criticised traditional
cephalometrics, largely on the grounds that it forces the reduction of information available on radiographs to point data. They claim that the reduced data misrepresents shape changes due to growth; for instance, growth is portrayed as a vector displacement rather than a generalised distortion.

Instead, a method using "biorthogonal grids", which is a computer-based representation of a cephalogram, is suggested as a more biologically relevant tool for craniofacial growth research.

**STEPS TAKEN TO REDUCE THE ERROR OF THE CEPHALOMETRIC TECHNIQUE**

In this study the following steps have been taken in an attempt to reduce the errors of the cephalometric technique:

1. The shadows of the ear-rod circles were routinely monitored on the head films to ensure that the x-ray beam passed at right angles to the midsagittal plane of the cephalostat.

2. Close attention was paid to the placement of patients in the cephalostat. For instance, a routine was followed which included seating the patient in such a way that the ear-rods exerted a slight upward pressure on the superior surface of the external auditory canal. Such measures were taken in an
attempt to standardise the replication of the skull position on successive exposures.

3. Where the two sides of a particular structure appeared as separate images on a radiograph, both sides were traced and an average was dotted in between them, as suggested by Bjork (1947). This average was utilised in drawing the different planes. It was noted that where the discrepancy between sides on a cephalograph was marked, it was also evident on all other cephalographs of that patient, even those dating back five or more years. The inference drawn from this observation is that skull asymmetry rather than head rotation in the cephalostat, was the reason that the two sides showed a discrepancy greater than that which one would expect as a result of divergent x-rays causing greater magnification of one side.

4. Where possible, landmarks lying in the midsagittal plane were utilised in this study. Notably, the mandibular plane is one of the exceptions.

5. Angular rather than linear measures have been used wherever it was feasible to do so.
6. Those landmarks that are readily definable and reproducible were favoured.

7. The cephalographs were carefully traced on "Kodatrace" acetate tracing sheets, using a transilluminating table in a darkened room. The materials used were a 2H pencil sharpened after each tracing, a "Unitek Cephalometric Protractor" as designed by Dr. A.T. Baum, a transparent millimetre rule, and a rubber.

8. Angular measurements to the nearest half degree and linear measurements to the nearest half millimetre, while not the smallest dimensions capable of being recorded, were considered to be reliable and reproducible.

9. A test was carried out to determine the amount of error inherent in the tracing technique, and is discussed under the following subsection "Error of the Tracing Technique".

10. This investigation is a study of short term profile changes, so that growth changes, which according to Moyers and Bookstein (1979) make conventional cephalometrics an inappropriate tool, are minimal.
ERROR OF THE CEPHALOMETRIC TRACING TECHNIQUE

To determine the amount of error inherent in the tracing technique, ten cephalograms were selected at random from the original sample of thirty two. These were retraced and measured twenty one days after the first tracing to eliminate memory bias. The first and second sets of measurements were then tabulated. (Table III). The mean difference, the standard deviation and the "t" values for each replicated measurement, were calculated and are set out in Table IV. The "t" values were compared with the relevant percentage points of the "t" distribution, in order to find the significance of the differences between the two tracings. The difference was not significant for any of the measurements at the 0.1 level of significance.
### Table III

**Difference and Second Tracings**

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</table>

Measurements of differences between first and second tracings. \( n = 10 \).
<table>
<thead>
<tr>
<th>su</th>
<th>0.68</th>
<th>0.44</th>
<th>0.10</th>
<th>N: Me</th>
</tr>
</thead>
<tbody>
<tr>
<td>su</td>
<td>0.24</td>
<td>0.60</td>
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<td>0.01</td>
</tr>
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<td>0.74</td>
<td>-0.10</td>
<td>Wp</td>
</tr>
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<td>su</td>
<td>0.29</td>
<td>0.55</td>
<td>0.05</td>
<td>SNP</td>
</tr>
<tr>
<td>su</td>
<td>0.05</td>
<td>0.46</td>
<td>0.10</td>
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</table>

<table>
<thead>
<tr>
<th>sig/not sig</th>
<th>&quot;t&quot; Value</th>
<th>S.D. of difference</th>
<th>2</th>
<th>Measurement</th>
</tr>
</thead>
</table>

| u = 10 |

**Tests for Significant Error of the Cephalometric Tracing Technique**

**Table IV**
Cephalometric Definitions
CEPHALOMETRIC LANDMARKS, PLANES, ANGLES AND LINEAR MEASUREMENTS USED IN THE PRESENT STUDY. (FIGURE II) Graber (1972 P.P. 432-433), Salzmann (1974 P.P. 183-190)

CEPHALOMETRIC LANDMARKS.

Sella (S). The midpoint of Sella turcica, determined by inspection. Generally, sella can be detected accurately on a lateral cephalogram, and it lies in the midsagittal plane.

Nasion (Na). The intersection of the internasal suture with the nasofrontal suture in the midsagittal plane. Since nasion is located on the outline of the cranium it is comparatively easy to identify, though Baumrind and Frantz (1971 a) found a vertical distribution of error for this landmark. The error may in part be due to its anatomic variation.

Pogonion (Pog). The most anterior point on the contour of the chin. Pogonion was located by dropping a tangent to the chin from nasion.

Porion Po. The most superior lateral point on the roof of the external auditory meatus. It is often located using the uppermost point of the shadow of the ear-rods, if these obscure the anatomical landmark.

Menton (Me). The lowest point on the symphyseal outline of the chin. It was determined by using the mandibular plane as a tangent to the symphyseal curve.
FIGURE 11

Cephalometric landmarks and planes used in the present study.
CEPHALOMETRIC PLANES.

Sella-Nasion Plane (S-N). A line joining sella (S) to nasion (N). This line denotes the anterior portion of the cranial base. Ricketts, Schulhof and Bagha (1976) prefer to use the Frankfort horizontal plane to the sella-nasion plane, but Wei (1968) in comparing the variability of five cephalometric planes, found the sella-nasion plane to be highly reliable and reproducible. The sella-nasion plane serves as a relatively stable base from which to appraise dynamic changes in the dentofacial complex.

Occlusal Plane

The occlusal plane was drawn from the midocclusal points of the first permanent molar to a point midway between the upper and lower central incisors. (Downs 1948).

Mandibular Plane. The mandibular plane was drawn tangent to the posterior portion of the lower border of the mandible and to the symphyseal curve. (Downs 1948). Other methods have located the plane anteriorly using the lowest anterior point on the lower border, but this point does not lie in the midline.

Y-Axis was constructed from sella, to the intersection of the N-P and mandibular planes passing through gnathion.

Facial Plane (N-P). A line from nasion to pogonion.

Long Axis of the Lower Incisor. A line passing through the incisal tip and root apex of the lower central incisor.
ANGLES

MANDIBULAR PLANE ANGLE

Formed by the intersection of the sella-nasion line with the mandibular plane. The position of sella may be high or low, with respect to a vertical profile line. This affects angular criteria, using the S-N plane as a base. However, in this investigation the mandibular plane angle is not being studied in relation to population norms, but rather to study change in the mandibular plane angle occurring as a result of treatment.

Y-Axis to S-N. This is read as the angle toward the profile of the face below the S-N line. It is used in this study, as a corroborative indicator of the change in direction of mandibular rotation and of the position of the chin point in the face.

Facial Angle SNP is also used here as a corroborative indicator of the change in the degree of recession or protrusion of the mandible in relation to the cranial base.

INCLINATION OF THE LOWER INCISOR

The angle between the long axis of the lower incisor and the mandibular plane.

LINEAR MEASUREMENTS

Overbite. Overbite was measured as the perpendicular distance between lines constructed from the incisal
edges of the maxillary and mandibular central incisors, parallel to the occlusal plane. This method was felt to most closely resemble the subjective appraisal of patients which led to the clinical diagnosis of deep overbite and hence to their inclusion in this investigation. The method of measuring overbite could also be readily applied to dental casts, if corroborative evidence was required.

Nasion-Menton. Changes in the inclination of the anterior teeth as a result of an unintentional inclined-plane effect of the bite plate as a result of jaw rotational effects (Bjork and Skieller 1972); and changes in the occlusal plane as a result of treatment, might effect the reading of the vertical overlap of incisors. Therefore a skeletal measure of anterior vertical height has been included in this investigation, being the distance between nasion and menton.
Methods & Results
MEASUREMENTS

Three experiments, involving separate sets of measurements from tracings of the thirty two cephalographs, were undertaken.

Experiment 1 consisted of recording the pre-treatment and post-treatment overbite, and mandibular plane angles (MP : SN). To corroborate these measurements the linear distance nasion to menton (N - Me), and the angles between sella-nasion and pogonion (SN : P) and between the Y axis and sella-nasion (Y axis : SN) were also tabulated. The differences between each of the before and after measurements were then calculated, and the mean difference subjected to "t" test statistical analysis to assess the significance of the differences.

Experiment 2 involved following a series of steps to reach a predicted value for the mandibular plane angle. This predicted value should correspond to the amount of bite opening recorded in experiment 1, if a hinge opening rotation of the mandible occurred during treatment.

The method devised consisted of the following steps: (figure 12)

Step 1. A line was drawn on the pre-treatment cephalograph tracing parallel to the occlusal plane; and at a perpendicular distance from the tip of the lower incisor equal to the amount of bite opening that occurred.
FIGURE 12
Graphic illustration of the method used in experiment 2. Showing a pre-treatment cephalometric tracing, and an overlay template of the mandible rotated about an estimated centre of rotation (X). The lower incisor tip rests upon a line parallel to the occlusal plane, and at a perpendicular distance from the upper incisal edge, equal to the amount of bite opening that occurred during treatment. The predicted mandibular plane angle is read between the original SN plane, and the template mandibular plane.
Step 2  A second tracing of the mandible including the tip of the lower incisor was made from the same cephalograph and superimposed upon the first tracing.

Step 3  A pin was placed ten millimetres anterior to porion, and parallel to the Frankfort plane. This pin position was estimated to be the approximate centre of the condylar head. The decision regarding its location was based upon the fact that many articulators and face bows, used in prosthetics, are calibrated on the assumption that the condylar head is 7.5 millimetres anterior to the ear rods. Allowing for some radiographic magnification; a position ten millimetres anterior to porion seems a reasonable representation of the centre of the condylar head. By trial and error it was determined that inaccuracy in placing the pin point of even a centimetre in any direction, made no discernible difference to the measurement subsequently obtained.

Step 4  The top tracing was rotated about the pin point until the tip of the lower incisor lay upon the line drawn in Step 1.

Step 5  After fixing the two tracings in their new position with cello tape, the new mandibular plane was measured with a protractor against the original sella-nasion line in order to obtain the mandibular plane angle that one would expect to correspond to the amount of bite opening accomplished during treatment.
The predicted mandibular plane angles were then compared to the actual post-treatment mandibular plane angles and the mean difference analysed for statistical significance using the "t" test.

Experiment 3. The pre-treatment and post-treatment inclination of the lower incisor was measured by recording the angle between the long axis of the lower incisor, and the mandibular plane. The differences between the two recordings were calculated and the mean difference analysed for statistical significance, again using the student's "t" test.
RESULTS

Experiment 1 In fourteen of the sixteen cases there was an increase in the mandibular plane angle coinciding with bite opening. One case showed no change, while another showed a slight decrease. The overall increase in the mandibular plane angle was found to be highly significant at the 0.0005 level of significance.

The other measurements also showed significant differences. The anterior facial height increased in all cases except the case mentioned above, that showed the decrease in the mandibular plane angle. The SN to pogonion angle decreased in eleven cases, remained unchanged in four, and increased half a degree in one case. The Y axis to SN increased in all but one case.

These changes are illustrated by Table VI which shows the mean difference, the standard deviation; the "t" value, and the level of significance for the measurements of overbite, MP:SN, N-Me, SN:P, and Y axis:SN. The precise figures are given in Table V.
TABLE V

Giving the measurements of Overbite (mm), MP : SN (degrees), Anterior Facial Height N - Me (mm), SN : P (degrees) Y axis : SN (degrees) recorded from the pre-treatment and post-treatment lateral cephalographs, and the difference between them. \( n = 16 \).

<table>
<thead>
<tr>
<th>Patient</th>
<th>Overbite (mm)</th>
<th>MP : SN (degrees)</th>
<th>Ant. Facial Height (mm) N - Me</th>
<th>SN : P (degrees)</th>
<th>Y axis (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>2nd</td>
<td>d</td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>AB</td>
<td>6.5</td>
<td>2.0</td>
<td>-4.5</td>
<td>22</td>
<td>23.5</td>
</tr>
<tr>
<td>CC</td>
<td>4.5</td>
<td>1.5</td>
<td>-3.0</td>
<td>29</td>
<td>31.5</td>
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<td>CH</td>
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<td>0.5</td>
<td>-5.5</td>
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<td>SH</td>
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<td>-4.0</td>
<td>31.5</td>
<td>34</td>
</tr>
<tr>
<td>JJ</td>
<td>6.5</td>
<td>1.5</td>
<td>-5.0</td>
<td>30.5</td>
<td>32</td>
</tr>
<tr>
<td>CKe</td>
<td>3.5</td>
<td>-2.5</td>
<td>-6.0</td>
<td>33</td>
<td>34.5</td>
</tr>
<tr>
<td>CKr</td>
<td>5.0</td>
<td>1.0</td>
<td>-4.0</td>
<td>39</td>
<td>40.5</td>
</tr>
<tr>
<td>EK</td>
<td>3.5</td>
<td>1.0</td>
<td>-2.5</td>
<td>40</td>
<td>44.5</td>
</tr>
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<td>TM</td>
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<td>1.0</td>
<td>-6.0</td>
<td>28.5</td>
<td>29</td>
</tr>
<tr>
<td>GM</td>
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<td>-1.0</td>
<td>-4.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Dra</td>
<td>5.5</td>
<td>0.5</td>
<td>-5.0</td>
<td>25.5</td>
<td>28</td>
</tr>
<tr>
<td>DRo</td>
<td>7.5</td>
<td>3.5</td>
<td>-4.0</td>
<td>32</td>
<td>37</td>
</tr>
<tr>
<td>PS</td>
<td>7.0</td>
<td>3.0</td>
<td>-4.0</td>
<td>37</td>
<td>36</td>
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<tr>
<td>RS</td>
<td>6.5</td>
<td>2.5</td>
<td>-4.0</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>AS</td>
<td>7.0</td>
<td>3.0</td>
<td>-4.0</td>
<td>31</td>
<td>33.5</td>
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<tr>
<td>MW</td>
<td>5.0</td>
<td>1.5</td>
<td>-3.5</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

1st = pre-treatment lateral cephalograph  
2nd = post-treatment lateral cephalograph  
d = difference between 1st and 2nd cephalograph measurements.
### TABLE VI

Showing the mean difference the standard deviation, the "t" value and the level of significance of the differences in overbite, MP : SN, N - Me, SN : P, and Y axis : SN. 
\( n = 16 \).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>( \bar{d} )</th>
<th>S.D.</th>
<th>&quot;t&quot; value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overbite (mm)</td>
<td>-4.343</td>
<td>0.978</td>
<td>-17.56</td>
<td>sig. at 0.0005 level</td>
</tr>
<tr>
<td>MP : SN (°)</td>
<td>2.188</td>
<td>1.690</td>
<td>5.01</td>
<td>sig. at 0.0005 level</td>
</tr>
<tr>
<td>N - Me (mm)</td>
<td>3.219</td>
<td>1.877</td>
<td>6.64</td>
<td>sig. at 0.0005 level</td>
</tr>
<tr>
<td>SN : P (°)</td>
<td>-1.500</td>
<td>1.690</td>
<td>-3.44</td>
<td>sig. at 0.001 level</td>
</tr>
<tr>
<td>Y axis : SN (°)</td>
<td>1.719</td>
<td>1.549</td>
<td>4.30</td>
<td>sig. at 0.0005 level</td>
</tr>
</tbody>
</table>

\( \bar{d} \) = mean difference  
S.D. = standard deviation  
\( t \) = the simplified formula for the two sample student's "t" test, to examine the mean difference between two samples of equal number and common variance.
Menezes'(1975a) control groups showed an average reduction of 0.7 degrees in the angle between the maxilla and the mandible over a nineteen month period. Williams and Hosilla(1976) also found that in most cases the mandibular plane angle closed during periods of normal growth. On the other hand, the sample group of this investigation experienced an average opening of the mandibular plane angle of 2.1 degrees over an average period of 3.9 months.

Anterior facial height measured between nasion and menton increased by an average of 5.2 millimetres in the male control group of Menezes' study, and by 2.0 millimetres in the female control group. This represents an average increase for both sexes of 3.6 millimetres over a nineteen month period.

In this study there was a smaller average increase in anterior facial height, of 3.2 millimetres over a much shorter (3.9 months) period of time.

**Experiment 2** In twelve of the sixteen cases, the actual post-treatment mandibular plane angle recorded, was less than the mandibular plane angle predicted on the assumption that a hinge opening rotation of the mandible had occurred.

Table VII gives the actual, and predicted figures for the mandibular plane angle, and the difference between them. Table VIII shows the mean difference, the standard deviation, and the "t" value, and the level of significance.
TABLE VII

Showing the actual post-treatment MP : SN, the predicted MP : SN, and the difference between them. n = 16.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Actual post-treatment MP : SN (degrees)</th>
<th>Predicted MP : SN (degrees)</th>
<th>d (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>23.5</td>
<td>25.5</td>
<td>2.0</td>
</tr>
<tr>
<td>CC</td>
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<td>0</td>
</tr>
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<td>LH</td>
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<td>26.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>SH</td>
<td>34</td>
<td>35</td>
<td>1.0</td>
</tr>
<tr>
<td>JJ</td>
<td>32</td>
<td>35.5</td>
<td>3.5</td>
</tr>
<tr>
<td>CKe</td>
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<td>43.5</td>
<td>3.0</td>
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<td>44.5</td>
<td>41.5</td>
<td>-3.0</td>
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<tr>
<td>TM</td>
<td>29</td>
<td>33</td>
<td>4.0</td>
</tr>
<tr>
<td>GM</td>
<td>28.5</td>
<td>29.5</td>
<td>1.0</td>
</tr>
<tr>
<td>DRa</td>
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<td>2.5</td>
</tr>
<tr>
<td>DRo</td>
<td>37</td>
<td>36</td>
<td>-1.0</td>
</tr>
<tr>
<td>PS</td>
<td>36</td>
<td>39.5</td>
<td>3.5</td>
</tr>
<tr>
<td>RS</td>
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<td>35.5</td>
<td>0.5</td>
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<tr>
<td>AS</td>
<td>33.5</td>
<td>36.5</td>
<td>3.0</td>
</tr>
<tr>
<td>MW</td>
<td>30</td>
<td>32.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

\[d\] = difference.

TABLE VIII

Illustrating the mean difference, the standard deviation, the "t" value, and the level of significance of the differences between the actual and predicted value of MP : SN. n = 16.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>d []</th>
<th>S.D.</th>
<th>&quot;t&quot; value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP : SN (°)</td>
<td>1.47</td>
<td>1.95</td>
<td>2.92</td>
<td>sig. at 0.01 level</td>
</tr>
</tbody>
</table>

Figures for table VIII are correct to two decimal places.
Experiment 3 Following treatment, fourteen of the sixteen cases demonstrated a highly significant proclination of the lower incisor, in relation to the mandibular plane. Two cases showed retroclination.

Table IX gives the pre-treatment and post-treatment inclination of the lower incisor, and the difference between them. Table X shows the mean difference, the standard deviation, the "t" value, and the level of significance.

To discount the effects of growth and eruption; the average proclination of the lower incisor of 2.84 degrees in relation to the mandibular plane, over the 3.9 months of this experiment, can be compared to Corelius and Linder-Aronson's study (1976). They found that an average proclination of 2.7 degrees occurred, but this was over a much longer period of three to four years.

Figures 13-20 are the pre-treatment and post-treatment cephalographs, intra-oral photographs, and dental-models of one male patient (A.S.), and one female patient (C.Kr.), that were selected as being representative of the treatment response seen in the sample generally.
TABLE IX

Showing the pre-treatment and post-treatment inclination of the lower incisor to the mandibular plane, and the difference between them.  n = 16

<table>
<thead>
<tr>
<th>Patient</th>
<th>1st</th>
<th>2nd</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>115</td>
<td>114</td>
<td>-1.0</td>
</tr>
<tr>
<td>CC</td>
<td>103</td>
<td>105</td>
<td>2.0</td>
</tr>
<tr>
<td>LH</td>
<td>96</td>
<td>102</td>
<td>6.0</td>
</tr>
<tr>
<td>SH</td>
<td>86.5</td>
<td>89.5</td>
<td>3.0</td>
</tr>
<tr>
<td>IJ</td>
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<td>1.5</td>
</tr>
<tr>
<td>CKe</td>
<td>101</td>
<td>101</td>
<td>0</td>
</tr>
<tr>
<td>CKr</td>
<td>89.5</td>
<td>92.5</td>
<td>3.0</td>
</tr>
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<td>EK</td>
<td>87</td>
<td>93</td>
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<td>86</td>
<td>95</td>
<td>9.0</td>
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<td>GM</td>
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<td>97.5</td>
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<td>DDr</td>
<td>90.5</td>
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<td>PS</td>
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<td>93.5</td>
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<td>AS</td>
<td>88</td>
<td>90</td>
<td>2.0</td>
</tr>
<tr>
<td>MW</td>
<td>100.5</td>
<td>103</td>
<td>2.5</td>
</tr>
</tbody>
</table>

1st = pre-treatment cephalograph
2nd = post-treatment céphalograph
d = difference.

TABLE X

Showing the mean proclination of the lower incisor to MP the standard deviation, the "t" value, and the level of significance of the differences.  n = 16.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>d</th>
<th>S.D.</th>
<th>&quot;t&quot; value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to MP (°)</td>
<td>2.84</td>
<td>2.84</td>
<td>3.87</td>
<td>sig.at 0.0005 level</td>
</tr>
</tbody>
</table>

NB. Figures for table X are correct to two decimal places.
FIGURE 13

Pre-treatment cephalograph of patient A.S.
FIGURE 14

Post-treatment cephalograph of patient A.S. Note the change in depth of anterior overbite from the previous cephalograph.
FIGURE 15

Pre-treatment (above) and post-treatment (below) intraoral photographs of patient A.S. Treatment time was four months.
FIGURE 16

Pre-treatment (above) and post-treatment (below) dental models of patient A.S.

Parallax - error to some extent masks the changes in overbite that occurred over the treatment period of four months.
FIGURE 17

Pre-treatment cephalograph of patient C.Kr.
FIGURE 18

Post-treatment (two months later) cephalograph of patient C.Kr. As well as an obvious change in the anterior overbite, the mandibular plane appears considerably steeper, however, this is partially due to a more downward orientation of the head in this second film.
FIGURE 19

Pre-treatment (above) and post-treatment (below) intraoral photographs of patient C.Kr. Treatment time was two months.
FIGURE 20

Pre-treatment (top), immediate post-treatment (middle), and two months post-treatment (bottom), dental models of patient C.Kr. The bottom models are an attempt to demonstrate that most of the overbite improvement remained stable, although two months post-treatment can be considered as "early days" yet.

Because the camera was centered over the middle pair of models, it was "looking" up at the pre-treatment models, so that even the under-surface is visible, and down at the two months post-treatment models. This tends to make the original depth of overbite and the improvement remaining four months later, less obvious than that seen clinically.
Discussion
DISCUSSION

Experiment 1. The results in most cases were consistent with what one would have predicted. Concurrent with bite opening, the mandibular plane angle opened by an average of 2.1 degrees. This finding is in agreement with the work of Bahador and Higley (1944), Atherton (1963), Richardson and Adams (1963), and Menezes (1975a), who also observed an increase in the mandibular plane angle following bite plate therapy.

The anterior facial height increased by an average of 3.2 millimetres, but this result was less than the average decrease in overbite of 4.3 millimetres. Perhaps this can be explained by the fact that the lower incisors became proclined during treatment. Menezes (1975a), too, found an increase in the anterior facial height of his experimental groups. The chin point swung backward in relation to the anterior cranial base, and this was also reflected by an average increase of 1.7 degrees in the angle between the Y-axis and the cranial base. These observations appear to be in agreement with Schudy's (1964 and 1968) conclusions regarding the relationship of the vertical dimension with the anteroposterior position of the chin. However, the relationship may be less obvious than Schudy seems to imply. In fact, the angle between S-N and pogonion only decreased by an average of 1.5 degrees, despite an average bite opening of 4.3 millimetres.

The highly significant decrease in the overbite in all cases, and by more than the average of 4.3 millimetres in seven cases, is not surprising, since the final
cephalograph was taken only after an improvement in the depth of overbite was clinically evident.

No attempt was made to screen the patients for low mandibular plane angle cases, since bite plate effects were being examined over a range of mandibular plane angles. Therefore, the suggestion by Schudy (1968), and by Isaacson, Isaacson, Speidel, and Worms (1971), that low angle cases might react differently from middle or high angle cases, cannot be rejected or confirmed on the basis of this study.

Although computing correlation coefficients between parameters, was considered beyond the aims of this investigation, it can be seen by inspection of Table V that the results of this study appear to be in keeping with the conclusions of Lulla and Gianelly (1976), who found that the cant of the mandibular plane at the start of treatment is not a good parameter with which to predict changes in other dentofacial measurements.

Just as Atherton (1963) and Richardson and Adams (1963) had found in some of their patients, one patient in this study (P.S.), showed inconsistent results that are difficult to explain. Simultaneous with a bite opening of four millimetres, the mandibular plane angle closed by one degree. However, the anterior facial height also decreased by one millimetre and the lower incisors proclined 4.5 degrees. Perhaps coincidently, this patient is also the youngest in the sample.

Experiment 2. Perhaps not quite as predictable as the results of experiment 1 were the findings of experiment 2. Since direct histologic examination of the relationship
of the condylar head to the glenoid fossa is not possible, the nature of the mandibular postural changes occurring as the bite opened, can only be speculated upon. One might have assumed that a simple hinge type of opening rotation occurred. However, it was curious to find, just as Atherton (1963) had found, that in many cases a fairly large decrease in overbite was coupled with a relatively small increase in mandibular plane angle. In fact, in two cases where the overbite decreased by six millimetres, the mandibular plane angle opened by only 1.5 degrees in one of these cases, and by 0.5 degrees in the other.

It was also noted that in three cases the actual increase in mandibular plane angle was greater than the value predicted according to the method previously described. This is contrary to twelve other cases where the mandibular plane angle was less than the value predicted. In fact, in only one case was the actual value equal to the predicted value.

These findings lead to the conclusion that either the method, or the assumption upon which it is based is incorrect. Since the method appears sound, it may be the assumption that is lacking. We are then led to postulate a more complex mandibular adaptation to bite opening than a simple rotation. Such a supposition would not be incompatible with findings of structural modifications to the temporomandibular fossa and condyles in animals, following altered orofacial function. (Breitner 1940 and 1941, McNamara 1973, and Sergl and Farmand 1975).
Experiment 3

A simple examination of the change in mandibular incisor inclination following treatment revealed the somewhat surprising result of a highly significant proclination of the lower incisor, by an average of 2.8 degrees. In one case the proclination was as much as nine degrees.

Bjork and Skieller (1972) suggested that as growth rotations of the jaws occurred, there were compensatory changes in the paths of eruption of the teeth. However, in the anterior region of the mouth, the inclination of the incisors was to a large extent determined by functional factors such as the presence of a deep overbite.

Correction of the deep overbite using a bite plate may have "unlocked" the lower anterior teeth and allowed the compensatory proclination to occur. Upper incisor inclination was assumed to have remained unchanged, since the incisal edges were splinted by the acrylic of the Sved plate. However, measurements of upper incisor inclination were not made, because only mandibular effects were being examined in this investigation.

Another way of explaining the lower incisor proclination that occurred during treatment, is to postulate that there was an inclined plane wedging effect of the bite platform operating against the lower incisors. Although the bite platforms were parallel to the occlusal plane, this does not necessarily mean that they were at right angles to the long axes of the lower incisors.
Bjork and Skieller's (1972) suggestion, and the results or this experiment if accepted, have important implications for treatment. Opening the bite early and allowing compensatory lower anterior proclination to occur, might influence any subsequent decision regarding premolar extractions. Bjork and Skieller have said that, "Extraction while the deep overbite is still present can lead to difficulties in finishing the treatment".
Summary & Conclusions
SUMMARY

1. The changes in various cephalometric parameters, of patients undergoing bite plate therapy for reduction of their deep anterior overbite were measured, to examine the effect of the bite plate upon mandibular posture.

2. The mandibular plane angle predicted on the assumption that one of the effects of the bite plate is to bring about a hinge opening rotation, was compared to the actual mandibular plane angle found in each case, following bite opening.

3. The treatment changes in lower incisor inclination were measured, as an indicator of the validity of the assumption that a deep overbite might prevent the occurrence of compensatory change in incisor inclination to mandibular rotation.
CONCLUSIONS

1. In many children exhibiting deep anterior overbite, the Sved bite plate appears to have the propensity, at least in the short term, to initiate a backward mandibular (opening) rotation.

2. Since, in most cases, the opening of the mandibular plane angle was less than one would expect of a hinge opening rotation; this hypothesis was rejected in favour of a hypothesis postulating a more complex, combined rotatory and translatory mechanism, to explain the mandibular postural change that occurred during bite plate therapy.

3. The prediction of the occurrence of lower incisor proclination following bite opening, was confirmed by most of the sample of this investigation. This may have been due to a releasing effect of the lower incisors from within the maxillary arch, or to other causes such as an inclined plane effect of the bite platform.
Appendix
STATISTICAL TERMS AND FORMULAE USED

The statistical terms and formulae used in the calculations (Hogg and Tanis, 1977) are as follows:

\[ \bar{d} = \frac{\sum d}{n} \]

where

- \( \bar{d} \) is the mean of the differences in a sample
- \( \sum d \) is the sum of those differences
- and \( n \) is the number in the sample.

(Unbiased) Standard deviation

\[ S.D. = \sqrt{\frac{\sum (d - \bar{d})^2}{n - 1}} \]

where

- \( S.D. \) is the (unbiased) standard deviation
- \( \sum (d - \bar{d})^2 \) is the sum of the squares of the deviations from the mean difference
- \( n \) as above.
"t" values

\[
t = \frac{d}{S.D. \sqrt{\frac{1}{n-1}}}
\]

where \( t \) represents the simplified formula for the two sample student's \( t \)-test, to test the mean difference between two samples of equal number and common variance. Put simply, it is a test of whether differences are significantly different from nought.

\( n - 1 \) are the degrees of freedom for the relevant \( t \) distribution:
\( d, S.D., \) and \( n, \) as above.
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