MINIMISING UNDESIRABLE MOLAR TIPPING DURING
FACE-BOW EXTRAORAL TRACTION

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Dental Surgery at the University of Sydney

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PART I

INTRODUCTION
THE FACE-BOW EXTRAORAL APPLIANCE

All orthodontic appliances use force to cause movement of dental structures. Intraoral orthodontic appliances use reciprocal forces between teeth and groups of teeth. Therefore, as force is applied to a tooth to be moved it is also applied reciprocally to other teeth or to another tooth which the orthodontist may not wish to move, for example:

![Closing loop](diagram)

**Fig. 1** Continuous outline represents position of lower cuspid and 2nd bicuspid teeth before application of reciprocal force. Dotted outline shows likely position of these teeth following application of force.

![Class II elastics in position](diagram)

**Fig. 2** Class II elastics in position. They will tend to move maxillary teeth distally but also mandibular teeth mesially as well as producing extrusion.
An extraoral appliance uses the neck or head surface as an anchor, thus eliminating the reciprocal effect on teeth other than those to be moved.

Fig. 3 Illustration of extraoral appliance devised by Kingsley in 1868 (from Meyer p. 254, 1968)
Points of application of the extraorally-anchored force can be located intra- or extraorally. Examples are given of extraoral appliances using different sites of force application:

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<th>Author</th>
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<th>Site of Application of Force</th>
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<td>1866</td>
<td>Swivel attachments at maxillary cuspids</td>
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<td>1951</td>
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<td>Kloehn</td>
<td>1953</td>
<td>To hooks on outer bows which are connected rigidly to inner bows</td>
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**TABLE I:** Examples of extraoral appliances using different sites of force application.

Table I shows that Kloehn has transferred the point of application of force (as well as the anchorage) from an intraoral.
to an extraoral site. By selectively positioning the outer bow hook, the clinician can vary the direction of the force and the point where it applies.

TERMINOLOGY

Many authors and all orthodontic catalogues refer to this type of appliance as the 'face-bow extraoral appliance'. In the past, terminology varied. For example, Freeman (1963) calls the cervical face-bow appliance 'cervical gear', and Ringenberg and Butts (1970) refer to the same apparatus as 'single arch cervical traction'.

'Kloehn head-gear' and 'Kloehn face-bow' seem to have become accepted terms for the face-bow appliance with long outer bows and a cervical neck strap. (Kloehn described this appliance in 1953). But Sandusky (1965) uses the term 'Kloehn' for the Oppenheim E arch, (described by Kloehn in 1947). It is important to distinguish between these two appliances, as the point of application of force is different. The face-bow appliance force is applied to the outer bow hooks, the Oppenheim appliance to two hooks welded to the anterior section of the E arch.

The best way to distinguish the appliances would seem to be to follow Merrifield and Cross (1970) using the term 'head gear' when other than the face-bow appliance is meant. Head gear would then include those extraoral appliances which attach to arch wires or loops on E arches.

Nowadays the preferred term for the different parts of the
face-bow are 'inner bow' to indicate the intraoral part, as distinguished from the 'outer bow' which lies extraorally.

'Inner arch', 'traction arch', 'wire bar', 'dental bow', 'labial arch' and 'intraoral bow', as synonyms for the inner bow, are less commonly used in present literature. Similarly 'yoke', 'traction bar', 'occipital bow', 'bridle', 'face bow' and 'outer arms' for outer bow, have fallen into disuse.
Fig. 4 Face-bow and molar bands.

Fig. 5 Cervical face-bow appliance.

Fig. 6 High-pull face-bow appliance.
DESCRIPTION OF APPLIANCE

The face-bow is usually made of stainless steel. It comprises two 'bows' joined by a soldered (or more recently laser-welded) joint in the anterior section. The inner bow is round in cross-section and its ends fit into tubes on the molar bands. Bayonet bends or stops prevent the ends from sliding through the tubes. (See figure 4 on facing page). The cross-sectional diameter ranges from 0.045in to 0.072in.

When the face-bow is in place and the force unit attached the lips should rest passively on the upper and lower surfaces of the joint between the inner and outer bows.

The outer bow is usually of thicker cross-section than the inner bow and may be longer or shorter than the inner bow. The ends of the outer bow form hooks to which the traction units attach.

Traction units comprise -

(a) the active component (elastic-band strap (see figure 5) or steel spring (see figure 6)), and
(b) a load-distributing device such as a wide neck strap (see figure 5) or head gear strap (see figure 6).
TYPES OF MOLAR MOVEMENT

'Tipping' occurs when points on the tooth's surface move at different rates and in different directions (also known as 'angular displacement' or 'tilt'). This treatise discusses mesio-distal tipping around a bucco-lingual axis that results from face-bow extraoral traction.

![Diagram of upper molar tipping around a bucco-lingual axis.]

**Fig. 7** Upper molar tipping around a bucco-lingual axis.

'Translation' describes that motion of a tooth in a specific plane when the points on the tooth's surface travel along parallel lines in the same direction and at the same rate (also known as 'bodily movement', 'parallel displacement' or 'translational displacement').

![Diagram of upper molar undergoing translation in the sagittal plane.]

**Fig. 8** Upper molar undergoing translation in the sagittal plane.
A combination of translation and tipping can occur when the tipping axis itself translates.

![Axis of rotation](image_url)

**Fig. 9** Upper molar showing a combination of tipping and translation in the sagittal plane.

**THE PROBLEM STATED**

Clinicians seldom use the face-bow extraoral appliance to produce tipping. For example, Armstrong (1971) says: 'many molars that have been tipped back relapse to their original position in a very short time unless occlusal forces upright the teeth by distal root movement' (p. 223).

Kloehn (1962) states: 'when the molar has been moved sufficiently distally it is important to have this tooth in its correct axial inclination for proper function and stability' (p. 235).

A survey of 110 of the author's patients with face-bow extraoral appliances showed that only one wore the appliance to cause molar tipping. In all others the desired type of movement was molar translation. However, the face-bow extraoral appliance frequently does cause unintended tipping of molars. Gould (1957), Greenspan (1970), Kuhn (1968), Worms et al (1973) and
McCrostie (1975) all report unintended molar tipping.

The writer observed unintended molar tipping in his patients wearing face-bow extraoral appliances. These observations led him to investigate the problem and later to write this treatise.

**CONSEQUENCES OF THE PROBLEM**

If the clinician using the face-bow appliance allows it to cause undesired molar tipping one or more of the following may happen:

(a) **Alteration of contact points.** As a tooth tips it disrupts the normal contact points with the adjacent teeth.

Wheeler (1974) states:

'The proper contact relation between neighboring teeth in each arch is important for the following reasons: (1) it serves to keep food from packing between the teeth, and (2) it helps to stabilize the dental arches by the combined anchorage of all the teeth in either arch in positive contact with each other' (p. 100).

(b) **Alteration in occlusion.** A tooth tipped to its correct antero-posterior position may not be able to occlude properly with its antagonist. Posselt (1964) depicts in table form interaction of causative factors, including occlusal disharmony:

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|          | bone resorption | (p. 85) |
(c) **Undesirable movement of other teeth through arch wires.**

If the tooth being tipped is connected to others by arch wires the other teeth may move in the vertical plane:

![Diagram of molar movement](image)

*Fig. 10* Tipping of molars due to face-bow appliances causing extrusion of anterior.

(d) **Increase of Class II by mesial crown movement.** Worms et al (1973) point out that anti-clockwise tipping of molars may cause the opposite of the desired effect:

![Diagram of headgear force](image)

*Fig. 9* A headgear force causing mesial movement of the molar crown and distal movement of the molar splices. The center of rotation (X) is very near to the center of resistance (·).

*Fig. 11* Diagram from Worms et al (1973) (p. 333)
(e) Progress retarded by 'see-saw' effect. When a clinician moving teeth with the face-bow appliance sees that tipping has occurred he will make adjustments to reverse the tipping action, thus re-uprighting the teeth. But, as a result, the tooth may be moved past its original correct inclination. Further adjustment will then be necessary. This method of tipping the tooth one way then another seems likely to prolong treatment compared with a direct bodily movement from the original to the corrected position.

(f) Tipping may cause opening of the bite. Thurow (1970) considers that tipping produces an occlusally-directed force vector which can cause extrusion of the tooth. If extrusion of a molar occurs then the height of the lower face must increase. For some patients this increase may not be desirable.

(g) Patient co-operation lessened. If a face-bow appliance causes several degrees of molar tip the inner-bow-outer-bow junction moves vertically, forcing the upper lip higher or impinging on the lower lip. This may cause patient discomfort. Just as visible progress may encourage a patient to wear the appliance more than the required hours, undesirable effects are likely to discourage co-operation. Co-operation is an essential
ingredient in successful treatment by the face-bow extraoral appliance.
PART II

REVIEW OF THE LITERATURE
PHYSICS OF MOLAR TIPPING

Gould (1957) made an analysis of the physics of tipping. He states that the 'rotational or tipping motion of the tooth is governed by the relation of the line of force to the fulcrum. And where the line of pull passes through the fulcrum there will be no tipping' (p. 327).

Thurow (1975) writes:

Cranial traction is usually applied to the molars by means of a face-bow adjusted to direct the force in a plane passing through their roots. If the center of support of the root lies on the plane of the applied force, there will be no mesiodistal tipping effects on the tooth. If the force is applied in a plane lying occlusal to the center of support, the tipping moment will tend to move the crown distally and thus augment distal molar movement. If the plane of the force is apical to the support, the molar crown will be tipped mesially. This is often a desired tipping effect, but it may prevent or actually reverse the intended distal movement of the molar. These general principles apply to molar tipping with any extraoral appliance, either cranial or cervical, that is attached to the molars (p. 606).

In modern terminology Gould's 'fulcrum' would be known as the 'centre of resistance'. This term was introduced by Haack (1963): 'translatory movements of teeth may be produced by application of a force at a point which we shall call the centre of resistance of the supporting structures' (p. 331).

Gould (1957) also said that the exact rotation centre or fulcrum (centre of resistance) is not known but must lie between the neck of the tooth and the apical region (p. 327). Burstone (1962) Haack (1963) Armstrong (1971) Oosthuizen et al. (1973) consider that the
centre of resistance of the molar lies in the middle third of the root. Worms et al (1973) claim that the centre of resistance is somewhere near the trifurcation of the roots and 'it may migrate towards the crown when the second molar is fully erupted' (p. 388).

'Centre of resistance' is used differently from 'centre of rotation'.

Burstone (1962) used centres of rotation as a means to describe movements of teeth. Thus, if the tooth is not translating but is merely tipping, the centre of rotation would lie near the centroid or geometric centre. As some translatory influence is introduced the centre of rotation moves away from the centroid until, when the tooth is translating, the centre of rotation is at infinity.

Worms et al (1973) were able to demonstrate clinically that the further the line of force of extraoral force is acting from the centre of resistance the closer the centre of rotation approaches the centre of resistance.

Thus centre of resistance is that point through which a force must be applied if translatory movement is to result. The centre of resistance is not located at any particular point on the tooth but would vary from tooth to tooth and with different conditions of the tooth's environment.

Centre of rotation is an axis about which rotation has occurred. The term is used to describe movements of teeth. That is, if the tooth is undergoing pure rotation the centre of rotation will lie
close to the centroid. As translatory influence is introduced the centre of rotation moves away from the centroid towards infinity.

Worms et al (1973) further developed the concept of centre of resistance in terms of molar teeth and extraoral force. They defined the magnitude of effective moments exerted on the tooth under extraoral traction as

\[
\text{force applied} \times \text{the perpendicular distance to the centre of resistance:}
\]

![Diagram](image)

**Fig. 5** In order to determine the moment in a headgear problem, choose any point (O) and determine the moments acting around it. Sum moments =

\[
F_{r0}b - F(d + b) = F_{r0}b - F_d - p_b, F_{r0} = F \sum \text{moments} = -F_d \text{ or counterclockwise. Conclusion: Force times its perpendicular distance to the center of resistance equals the effective moment.}
\]

**Fig. 12** From Worms et al (1973) (p. 390)

Thurow (1970) defines moment as a 'rotating influence that causes the object to which it is applied to rotate or tip or spin' (p. 97).
Then, to determine the moment exerted by the face-bow appliance, the line of action of the force and the centre of resistance must be located.

**THE LINE OF ACTION OF THE FORCE**

The line of action of the force as applied by the face-bow extraoral appliance was first defined by Gould in 1957 as 'along the elastic band' which connects 'the hook on the nylon helmet to the traction arch hook'. ('Traction arch' is equivalent to outer bow).


Ricketts (1973), by saying that 'transferring the molar tube to the gingival aspect of the band moves the force closer to the centroid of the tooth', implies that the line of action of force is related to the position of the molar tube into which the inner bow fits. Worms et al (1973) refute this, saying that 'given the identical position of the outer face-bow hook and, therefore, a constant force vector to centre of resistance, distance and position of the headgear tube on the molar crown will give the same molar movement' (p. 394).

Barton (1972) claims that the 'line of pull is determined by extending a line through a point equal distant from the tip of the outer bow and the molar tube toward the line of pull' (p. 527). He gives no explanation for this arbitrary statement.
Thus, two points of reference are needed to define the line along which the force will tend to act.

The first is the outer bow hook, or in general physical terms, the point of application of the force. This point will tend to move as a function of the applied force.

The second is the anchor or stationary point. The outer bow hook, if it were free, would tend to move to this point. The writer calls it the 'hook target'. A pulley system best illustrates the concept of hook target:

![Diagram of hook target in a pulley system]

Fig. 13 Hook target in a pulley system

Commercial orthodontic headgears do not have pulleys. The equivalent to hook target would be the elastic hook on the Gould headgear.

![Diagram of Gould face-bow appliance]

Fig. 14 Gould face-bow appliance
However, the position of the outer bow hook may change once force is applied to it.

Gould (1957) assumed that the tooth, the band, the tube and the traction arch together constitute a rigid body once the elastic has been applied. Worms et al. (1973) also claim that the activated face-bow corresponded to the correct force system rather than passive face-bows.

But, if the force varies (e.g. with decay of elastic force) or if the tooth changes its orientation relative to the face-bow in response to the applied force or if the operator adjusts any part of the appliance, the tension within the bow is likely to alter. So too will the shape of the face-bow and therefore the line of action of the force.

Thurow (1970) illustrates how 'a very light force on this appliance may produce a mesial movement on the molar while a stronger force drops the bow and reverses the effect to a distal tipping moment'.

*Fig. 15 From Thurow (1970)(p. 209) showing the effect of different force levels on the shape of the face-bow.*
Worms et al (1973) suggest an increase in inner bow cross section from the 0.045in, which is commonly used, to 0.072in. This change will give a fourfold increase in rigidity, reducing the flex during loading and reducing the problems mentioned.

Thus, once the appliance has been activated the line of action of the force delivered by the face-bow appliance runs from the outer bow hook to the hook target. The next sections consider the effect of different positions of the hook target and of the outer bow hook.

**EFFECT OF VARYING HOOK TARGET POSITION**

Besides altering the line of action of extraoral force, the placement of the hook target will determine molar movement in the vertical plane: 'cervical pull headgear exerts extrusive force while high pull headcap yields intrusive force on the permanent first molars' (Greenspan 1970) (p. 491).

Gould (1957) used a nylon net headcap for anchorage. Hooks were attached which could be 'raised or lowered to produce an upward or downward force as required'. The forces produced are not, of course, purely upward or downward. As he varies the headcap hook position Gould changes the ratio of distal (horizontal) force to vertical force.

So that, if the hook target and centre of resistance of the tooth are in a horizontal plane no vertical effect should be produced. The resulting movement in response to this force should
be distal and horizontal:

**Fig. 16** Positions of hook target, outer bow hook and centre of resistance which should result in horizontal translation of the molar.

Then, the greater the angle of the line hook-target-to-centre-of-resistance with the occlusal plane, the greater the vertical component of force (Figs. 17 and 18):

**Fig. 17** Effect of lowering hook target on vertical force component.
Increased intrusive effect

*Fig. 18* Effect of raising hook target on vertical force component.

Thurow (1970) shows how different vectors (in between horizontal and vertical) are resolved into horizontal and vertical components:

*Fig. 4-5.* Vector analysis showing effect of angle on relative horizontal and vertical vectors.

*Fig. 19* Diagram from Thurow (1970) (p. 95)
FACTORS WHICH ALTER THE EFFECT OF VERTICAL FORCE COMPONENTS

When a force acts on a tooth in a certain direction the tooth will not necessarily move in that direction. Other forces may deflect it from this course. These include the forces exerted by the supporting structures and by the occlusion. The time the appliance is worn and the force exerted will also change the net amount of vertical movement.

(a) Role of supporting structures

Thurow (1970) says that 'periodontal membrane fibres are more resistant to apical than occlusal movement' (p. 115). According to Harvold (1974) a tooth maintains a tendency to extrude throughout life.

(b) Role of occlusion

Giving the theoretical basis for the use of activator appliances, Harvold (1974) claims that tooth extrusion ceases when occlusal forces reach a certain level, that only a minimum of continuously applied force is required to stop tooth extrusion and that intermittent forces can halt extrusion.

Further, Harvold claims that by isolating a tooth from occlusal forces on an intermittent basis (less than 14 hours a day), extrusion (and alveolar height) can be increased.

Kuhn (1968) points out that individuals vary in their ability to resist posterior tooth eruption during orthodontic
treatment. He says 'skeletal characteristics may alert the clinician to the susceptibility (of the patient) to bite opening' (p. 340).

Ricketts (1960) says 'Cases that are retrognathic, exhibit skeletal open bite, have diverging profiles and high manidublar planes are the least likely to resist extrusive components of force'.

Sassouni (1969) explains that in the case of skeletal deep bite, when the posterior vertical chain of muscle is strong and anteriorly positioned, great depressive action is transmitted to the dentition. In skeletal open bite the masseter and temporal muscles are underdeveloped. Molars are under the impact of these muscles.

He lists the characteristics for identification of skeletal deep bite types:

'The total posterior height (sella to gonion) is nearly equal to the total anterior facial height (supra-orbitale to menton). The lower face height (ANS-Me) is smaller than the upper face height (SOr-ANS). The facial breadths (minimum frontal and bigonial diameters) tend to be equal to total facial height, giving a square appearance from the frontal view. The gonial processes are flared laterally, indicating strong masseter action. The ramus is long, tending to equal the length of the corpus. The ramus is broad anteroposteriorly with a large coronoid process, indicating a strong temporalis muscle. This is further suggested by a large infratemporal fossa and an extensive temporal fossa, the medial line of which in extreme cases tends to meet that of the opposite side and to form a sagittal crest' (p. 111).
Sassouni goes on:

'most of the characteristics of the open-bite type are directly opposite those of the deep bite' (p. 112).

He diagrammatically illustrates the differences between the two basic types with vertical disproportions:

Skeletal deep bite

Skeletal open bite

Fig. 20a Illustration from Sassouni (1969) (p. 111).

Fig. 20b Illustration from Sassouni (1969) (p. 113)

(c) Force of appliance wear

The more hours a day that the force is acting, the less time the tooth has to recover.

Kuhn (1968) states that 'there seems to be a maximum time level from which a specific dentition can recover from an extrusive movement of the posterior teeth' (p. 344).

Further, he states 'the greater the time that an extrusive mechanical movement is placed on the posterior teeth, the less probable these teeth can resist total net eruption' (p. 344).

Ringenberg and Butts (1970) say that the mandibular plane angle may be preserved when wear of the cervical appliance
is intermittent (p. 184).

On the effect of force and duration of appliance wear Thurow (1970) writes that 'strong forces and full-time use can increase the occlusal movement of the molar. Moderate forces used half-time combined with careful avoidance of molar tipping can keep the occlusal vector at a sufficiently low level that normal occlusal function can resist elongation of the tooth' (p. 214).

**CONSEQUENCES OF MOLAR MOVEMENT IN THE VERTICAL PLANE**

(a) **Effect on patient appearance**

Kuhn (1968): 'The control of posterior tooth eruption is the most manageable factor available to the orthodontist in the overall control of anterior vertical dimension of the face' (p. 340).

Schudy (1963) adds that facial aesthetics is significantly altered by rotation of the mandible.

Ricketts (1960) calculated that for each millimetre of molar extrusion there is a three millimetre increase in the lower face height, measured from the anterior nasal spine to gnathion.

Also, as lower face height increases it becomes necessary to extrude incisors to maintain inter-incisal contact. This can cause an excessive display of gingival tissue above the incisor crowns (Kuhn 1968).

In contrast, Watson's high pull face-bow study (1972) showed that overbite was increased by 2.7mm a year. This type of effect
would be detrimental to the treatment of a patient's deep anterior bite problem.

Poulton (1974) reports an instance of the extrusive effect of cervical traction causing unsatisfactory profile changes. During treatment, 6.0mm of vertical development of the upper molars occurred. A 'sliding genioplasty' operation was necessary after treatment to mask the lack of forward mandibular movement.

(b) Effect on Class II molar correction

Extrusion of molars will tend to make Class II molar correction more difficult. 'The lower first molar moves distally 0.5mm with each 1mm of upper first molar extrusion' (Merrifield and Cross 1970) (p. 441).

Conversely Watson (1972) recommends 'that intrusion of the upper first molar aided tilting of the occlusal plane upwards in the posterior region. This is stated to have a beneficial effect toward the Class II correction according to Woodside and Harvold' (p. 574).

CERVICAL FACE-BOW APPLIANCES

The direction of cervical extraoral force applied to the face-bow ranges between 20° to 37° to the occlusal plane and below it, with an average of 25°.

Various writers blame cervical face-bow appliances for adverse patient reactions. For example, Merrifield and Cross (1970) group together such effects as 'relapse of Class II cases, lack of facial
improvement, difficulty of reducing the ANB angle, upper second molar problems, 'toothy smiles' and 'mandibular rotation' as 'cervical face-bow reaction' (p. 435).

Schudy and Schudy (1975) say 'cervical face-bows should seldom, if ever, be used on patients with any of the following characteristics: 1) open bite tendencies, (2) muscle strain, (3) relatively short lips, (4) gummy smile, (5) excessive relative ANS-to-Mn distance, (6) flat worn cusps, (7) large occluso-mandibular plane angle, (8) large palato-mandibular plane angle, (9) large frankfort-mandibular plane angle, (10) large SN-mandibular plane angle, (11) large gonial angle. Cervical face-bow headgears apply particularly well to patients with characteristics opposite the above' (p. 68 and p. 69). They reason that '75% of patients have one of the characteristics mentioned as contra-indicating cervical traction and thus only 25% of patients should wear cervical traction' (p. 69).

On the other hand, Ringenberg and Butts (1970) found a statistically significant decrease in the angle FMA during cervical face-bow treatment. But the treatment time ranged from 11 to 47 months, indicating that daily wear must have been low. This would permit the occlusion to recover from the extrusive effect of the appliance. So it is doubtful whether their observations could be applied to those intensive headgear treatments report by Armstrong (1971), where up to 1cm. distal movement is accomplished by full-time wear in less than six months.

Baumrind (1973), comparing the effects of cervical and high-pull
face-bow appliances, found that 'on the average the direction of force applied had little effect on change in the mandibular plane angle' (p. 454).

However, the writer doubts if the mandibular plane angle truly indicates whether treatment affects the lower face height, and thus the patient's appearance:

Poulton (1967) and Schudy (1965) concede that increase in alveolar height due to treatment can be compensated for by condylar growth.

In Poulton's case report mentioned above (p. 28) the mandibular plane to SN angle had increased only one degree despite quite marked increase in facial height.

Bjork (1969) has shown that there are remodelling changes along the lower border of the mandible during growth.

**HIGH PULL FACE-BOW APPLIANCES**

Hilgers et al (1971) recommend high pull face-bow appliances for those patients with 'high mandibular plane angle (FMA), high ANB discrepancy, open bite cases, patients who have a deficient chin (pogonion) and patients who have a 'gummy' smile line' (p. 251).

In skeletal open bites Subtelny and Musgrave (1975) recommend the use of high pull headgear 'designed not to erupt the maxillary molar teeth further and if possible to intrude them' (p. 438).

Baumrind (1975) found 'clear and dramatic evidence of upper molar intrusion in the high pull sample' (p. 453).
Poulton (1967) says that there were generally fewer problems with broken face-bows and loose bands with high pull appliances. **HORIZONTAL-PULL APPLIANCES**

Armstrong (1971) proposes a combination of high and low pull face-bow traction where horizontal distal force is required. The objectives of this force are

'1. to move the molars or the maxillary arch distally, either bodily or with some tipping without extrusion
2. to prevent forward movement of the upper posterior teeth in extraction cases without concurrent extrusion
3. to restrain forward growth of the maxilla without increasing its vertical growth' (p. 224).

**LOCATION OF THE OUTER BOW HOOK**

The position of the outer bow hook is governed by -

(a) the length of the outer bow in relation to the length of the inner bow

(b) the angle the inner bow makes with the outer bow.

Greenspan (1970) illustrates various outer bow positions:

![Diagram of outer bow positions](image)

*Fig. 21 Diagram from Greenspan (1970) showing outer bow positions (p. 488).*
Gould (1957) illustrates how lengthening the outer bow affects the position of the outer bow hook. If the same line of action of force is to be kept the angle of the outer bow to the inner bow must be varied:

\[ \text{Diagram from Gould (1957) (p. 329). Motion of upper right molar with cervical anchorage. Heavy straight arrows indicate directions of translational movements, curved arrows indicate tipping displacements.}
\]

- a. Long face-bow with upward angle, line of force apical to axis (Result: Mesial tipping, distal and extrusive movement).
- b. Long face-bow with downward angle, line of force apical to axis (Result: Mesial tipping, distal and extrusive movement).
- c. Short face-bow, line of force oclusal to axis (Result: Distal tipping, distal and extrusive movement).
(a) **Length of outer bow**

Gould (1957) employs a 'short' outer bow in clinical practice (although he showed that different outer bow lengths can be used with the face-bow appliance):

![Diagram of a face-bow appliance](image)

*Fig. 23 Part of Gould's 'present equipment for distal movement of upper molars' (1957) (p. 323)*

Worms et al (1973) show that it is possible to reduce rotation tendencies as a molar begins to change position:

![Diagram illustrating changing centers of rotation](image)

*Fig. 7 Illustrates changing centers of rotation with a constant source of force. As the molar rotates, the facebow rotates. The perpendicular distance between the headgear force vector and the molar center of resistance decreases causing a migration of the center of rotation toward infinity.*

*Fig. 24 Illustration from Worms et al (1973) (p. 391)*
Worms et al. (1973) show varying lengths of outer bow all having the same effect, translation, on the molar:

*Fig. 10* Headgear facebows with varying outer bow lengths A., A., A. All create molar translation because the resultant headgear force vector passes through the center of resistance (.), the center of rotation (X) is at infinity (\( \infty \)).

*Fig. 25* Diagram from Worms et al. (1973) (p. 393)

These authors also propose a prototype adjustable face-bow. They therefore show no preference for short, medium or long outer bows:

*Fig. 26* Worms et al. (1973) caption this diagram: "Adjustable face-bow mechanism. The outer bow hooks can be adjusted by sliding variously designed hooks into sleeve and locking in place (p. 400)."

Greenspan (1967) developed Gould's flywheel analogy to produce
charts of molar action with short, medium and long outer bows. One of these charts (for cervical anchorage) is shown:

![Diagram showing movement of maxillary molars with cervical appliance](image)

**Fig. 3.** Chart indicating the movement of maxillary molars when a cervical appliance or neckstrap is used with variations in the length and inclination of the outer bow. The resultant force vectors of the nine possible combinations of these two variables can be found by matching the proper row (inclination) and column (length). The size and boldness of the straight arrows are proportional to the direction of expected tooth movement. The size and number of the curved arrows likewise indicate the relative amounts of tipping produced.

**Fig. 27** Diagram from Greenspan (1970)(p. 488)

Greenspan further says 'that exceedingly long or short outer bows direct the force further away from the tooth's centre of rotation and thus provide excess tipping (p. 487).

Hilgers et al (1971), speaking about high pull headgear, claim that a longer outer bow creates a more 'vertical force and a shorter outer bow creates a more horizontal force if all other variables are held constant' (p. 251).
Poulton (1964) recommends outer bows extending past the molars even where high pull anchorage is used but does not give reasons for his choice.

Armstrong (1971) recommends the short outer bow claiming that it does not deflect or deform as much as the long outer bow, when heavy force is applied. Watson (1972) and McCrostie (1975) both prefer the short outer bow.

Kuhn (1968) illustrates the action of the face-bow appliance with differing lengths of outer bow, but indicates no preference for a specific length:

**OCCIPITAL HEADGEAR TO FACE BOW**

**RESOLUTION OF FORCES PLUS MOMENTS**

(A) HOOK POSITION ON OUTER BOW ANTERIOR TO MOLAR WITH DISTAL FORCE ABOVE CENTER OF RESISTANCE

THREE DIFFERENT PLACEMENTS OF HOOK ON OUTER BOW

(B) HOOK POSITION ON OUTER BOW SLIGHTLY ANTERIOR TO MOLAR WITH DISTAL AND INTRUSIVE FORCE THROUGH THE CENTER OF RESISTANCE

(C) HOOK POSITION ON OUTER BOW SLIGHTLY POSTERIOR TO MOLAR WITH DISTAL FORCE BELOW CENTER OF RESISTANCE

*Fig. 28* Diagram from Kuhn (1968) (p. 346)
(b) The angle that the outer bow makes with the inner bow

In the previous section on 'length of outer bow' authors Gould (see page 33) Worms et al (see page 33) and Kuhn (see page 36) have shown how the angle of outer to inner bow alters the line of force and is used to orient the line of force once hook target position and outer bow length have been chosen.

However, Greenspan (1970) claims that, with the straight pull occipital appliance, 'if the outer bows are bent upwards extrusion will result and intrusion of the permanent molars should occur when the outer bow arms are bent downwards' (p. 491).

Oosthuizen et al (1973) claim that 'the vertical force component becomes intrusive if the position of the hook of the outer bow is changed to a level lower than that of a plane passing through the point of origin of the force and parallel to the occlusal plane. This circumstance may obtain if the outer bow is long and is bent considerably downward' (p. 227).

The implant study of Melsen and Enemark (1969) compares the action of cervical face-bow appliances in causing various movements, including the extrusion caused to upper first molars. One group of patients wore the outer bows bent 20° upward in relation to the inner bows and the other 20° downward.

The two groups showed no significant difference in the extrusion of the upper first molar. However, the 'outer bow down' group showed a significantly high amount of distal crown
tipping.

This study would suggest that the angle of outer to inner bow has its main effect in directing the line of action of the extraoral force rather than affecting the proportion of vertical to horizontal force on the upper molar.
SUMMARY OF REVIEW OF LITERATURE

The available literature contains a number of theories as to the causes of tipping of a tooth under face-bow extraoral traction. The location of the tooth's centre of resistance in relation to the line of force applied will determine whether the tooth tends to tip or not and, if it tips, whether clockwise or anti-clockwise.

Further, the line of force is altered by varying the positions of the outer bow hooks and hook targets.

The action of the face-bow extraoral appliance as discussed in the literature could be summarised:

(a) Translation of the molar is possible only in the direction parallel to a line between the centre of resistance of the upper first molar and the hook target. To achieve the movement, the outer bow hook must lie on that line (see figure 29):

![Diagram showing the action of the face-bow extraoral appliance](image)

**Fig. 29** Conditions necessary to produce translation of upper molar with face-bow appliance
(b) An intrusive component of force as well as a distal component of force is introduced when the hook target is above a line projected posteriorly through the centre of resistance of the molar parallel to the occlusal plane. The greater the angle that the line between the hook target and the centre of resistance makes with the occlusal plane the greater the intrusive component of force (see figure 30):

![Increased intrusive effect](image)

Fig. 30 Effect of raising hook target on vertical force component.

(c) An extrusive component of force as well as a distal component of force is introduced when the hook target is below a line projected posteriorly through the centre of resistance parallel to the occlusal plane. The greater the angle that the line between the hook target and the centre of resistance makes with the occlusal plane the greater the extrusive component of force (see figure 31):
Increased extrusive effect

**Fig. 31** Effect of lowering hook target on vertical force component.

(d) Components of force which tend to cause distal root tipping are introduced when the outer bow hooks lie above the line hook-target-point to centre-of-resistance (see figure 32):

**Fig. 32** Conditions likely to cause distal root tipping.
Components of force which tend to cause distal crown tipping are introduced when the outer bow hook lies below the line hook-target-point to centre-of-resistance (see figure 33):

![Diagram showing force components and points of interest for distal crown tipping.]

**Fig. 33** Conditions likely to cause distal crown tipping.

However, all statements from the literature and the above statements summarising the literature refer to particular conditions which will tend to produce certain movements. Not one author mentions whether the same conditions apply or are changed once the tooth has moved in response to the applied extraoral forces.

Thus the literature omits reference to the effect of movement of dental structures on the relation between the line of force and the centre of resistance.

Further omitted from the literature is an analysis of those features of headgear design which may aid the clinician in visually aligning force vectors with centres of resistance.
PART III

EXPERIMENTS WITH WOODEN MODELS

AND GEOMETRIC ANALYSES
PURPOSE OF EXPERIMENTS WITH WOODEN MODELS

The writer conducted a number of experiments in his own laboratory to try to gain evidence on these gaps in the literature. The main aims were:

(a) To test the hypothesis that the force directed on a free body through the centre of resistance will tend to cause translation of that body.

(b) To establish whether there is any constant relationship between the point of application of force, the line of action of the force, the centre of resistance and the nature of movement that follows.

(c) To study the effect that the movement of dental structures may have on the relation between the line of force and the centre of resistance.

DESCRIPTION OF EXPERIMENTS

In the first series of experiments, force was applied by means of a string passing over a horizontal pulley to pins inserted at various points on a wooden tooth shape.

Worms et al (1973) described a similar experiment but used 'force applied via an elastic'. The use of elastic would seem to be unwise. It produces acceleration factors which are not present in vivo because of the effective viscosity of the tooth's supporting structures. Therefore, the writer used a horizontal pulley and moved the string slowly by hand.

The pulley is placed in a line 'horizontal' to the tooth's
approximate centre of resistance. If the string were connected to a pin which happened to be at the centre of resistance, horizontal translation should result.

Experiment 1

The string is pulled until all rotatory movement ceases and translation occurs for a short distance. A line is then drawn to represent the continuation of the string (see figure 34):

![Figure 34](image)

Fig. 34 Photograph of experiment 1. The wooden tooth has tipped from the original position then translated for a short distance. A line representing a continuation of the string is drawn on the 'tooth's' surface.

Experiment 2, 3 and 4

The 'tooth' is then returned to the starting position and the pin moved to a new location. The procedure is repeated by pulling the string slowly until translation occurs for a short distance. A new line is then drawn to represent the continuation of the string. New pin locations are selected for each of the experiments, numbers
2, 3 and 4 (see figures 35, 36 and 37):

Fig. 35  Experiment 2 uses the same procedure. The pin is in a different position on the 'tooth'.

Fig. 36  Experiment 3. The pin position is changed again and the procedure repeated.
Experiment 5

The four lines representing the extensions of the string were found to intersect at a point. If a pin was placed at this point and the string connected to the pin, the 'tooth' translated when the string was pulled. This point seems to be the centre of resistance of structures supporting the wooden tooth (see figure 38):

Fig. 38 Experiment 5. The pin is placed at the 'centre of resistance'. The wooden tooth translates from the original position.
Experiment 6

All pins were then removed and a heavy wire apparatus fitted to simulate the action of a face-bow. Firstly, the wire is bent like a short outer bow - that is, the outer bow hook lies on the side of the tooth opposite the pulley or 'hook target'. The hook is placed so that the string (the line of force) does not pass through the 'centre of resistance' (see figure 39):

![Image of Experiment 6](image)

**Fig. 39** Experiment 6 simulates short outer bows. The line of force is placed to avoid the 'centre of resistance'.

As the string is pulled some translatory effect occurs but this is overshadowed by the large amount of tipping. The proportion of tipping increases as the action proceeds (see figure 40):
Fig. 40  Experiment 6 (continued). Wooden tooth undergoing a large amount of tipping and a small amount of translation (due to the line of force not passing through the centre of resistance and the use of short outer bows)

Not until rotation has turned the tooth upside down does translation occur without further tipping (see figure 41):

Fig. 41  Experiment 6 (continued). The experiment carried to its illogical conclusion. The wooden tooth, though upside-down, is now translating.
Experiment 7

Next the string is passed as close as possible to the 'centre of resistance'. The very small distance (about 1 mm) between the line of force and the centre of resistance is sufficient to start the same type of tipping which was seen in figure 40 and 41, but to a lesser extent (see figures 42 and 43):

**Fig. 42** Experiment 7 simulating short outer bows. The line of force is close to centre of resistance.

**Fig. 43** Experiment 7. The wooden tooth is tipped from original position, even though the line of force was close to centre of resistance.
Experiment 8

A new wire configuration is constructed to simulate a long outer bow where the outer bow hook lies between the 'tooth' and the hook target (see figure 44). The line of force is arranged to be more than twice the distance from the centre of resistance than was the case in experiment 7. A relatively small amount of angular displacement (in proportion to moment created) is seen before translation begins (figures 45 and 46 – compare with figures 39, 40 and 41):

*Fig. 44* An experiment simulating the use of long outer bows. The line of force misses the centre of resistance by more than twice the distance in the previous experiments using shorter outer bows.
Fig. 45 Wooden tooth tipping from the original position as the string is slowly moved by hand.

Fig. 46 Wooden tooth is now translating, with altered axial inclination.

Experiment 9

With the long outer bow, there is no difficulty maintaining translatory movement when the line of force is arranged close to the 'centre of resistance':
CONCLUSIONS FROM EXPERIMENTS WITH THE WOODEN MODEL

The behaviour of the model as force is applied from different directions demonstrates:

1. As indicated in the literature, rotational effect will tend to occur if the line of force is not directed through the centre of resistance of structures supporting the body.
2. As the perpendicular distance from the line of force to the centre of resistance decreases, the tendency to tip decreases and the tendency to translate increases.

3. It is possible to reduce rotation tendencies as the wooden tooth moves by altering the position of the outer bow hook.

A series of geometric illustrations were developed to establish the relationship between the length of the outer bow and the amount of any tipping.
Fig. 49 Diagramatic illustration of a face-bow appliance with short outer bows. The line of extraoral force misses the centre of resistance. A moment equal to \( M_d \) is acting on the molar.

Fig. 50 The moment acting on the molar has increased with tipping of the molar (\( M_d' \) is greater than \( M_d \) in figure 49).
GEOMETRIC ANALYSIS OF THE EFFECTS OF SHORT AND LONG OUTER BOWS.

The diagrams (figures 49, 50, 51 and 52) illustrate the mechanical difference between the actions of short and long outer bows. These are experimental situations. Incisor outline is drawn for the reader's orientation.

With short outer bows the displacement of the line of action of the force from the centre of resistance causes a moment to be set up equal to \( M_d \) in figure 49.

As this moment tips the molar, the line of force is displaced further from the centre of resistance, increasing the moment exerted on the tooth (figure 50). The moment \( M_d' \) in figure 50 is greater than \( M_d \) in figure 49.

When the same moment is applied using outer bows which extend past the molar (figure 51) the moment decreases as movement occurs (figure 52).

\[ \text{Fig. 51 Diagramatic illustration of a face-bow appliance with long outer bows. The line of extraoral force misses the centre of resistance causing a moment equal to } M_d \text{ to be exerted on the molar.} \]
Fig. 52 The moment (M₁₄) acting on the molar has decreased with tipping of the molar. Compare with figure 51.

This analysis suggests that face-bow appliances with short outer bows have an inherent shortcoming: as structures move in response to the extraoral force, the mis-alignment error (the perpendicular distance between the line of force and the centre of resistance) increases.

In contrast, face-bow appliances with long outer bows have the advantage that the initial alignment error decreases as movement proceeds.

So, if the clinician wishes to reduce initial angular displacement as much as possible for a given alignment error, should he use outer bows which situate the outer bow hooks just past the molars or will an even longer outer bow produce better results? This question led to further experiments.

GEOMETRIC ANALYSIS OF THE EFFECT OF INCREASING THE LENGTH OF LONG OUTER BOWS

Figure 52 indicates that as movement progresses using the long outer bow the moment causing the tipping effect decreases. If the
is allowed to continue the moment will disappear altogether. In the absence of any other forces, translation should then occur. However, the tooth has been tipped through a number of degrees and will continue to translate with the altered axial inclination. This is the initial angular displacement caused by the initial alignment error (see figure 53):

\[ \theta \text{ - initial tip} \]
\[ \delta \text{ - initial alignment error} \]
\[ A \text{ - hook target} \]
\[ B \text{ - outer bow hook} \]
\[ C \text{ - centre of resistance} \]

**Fig. 53** An upper molar under face-bow extraoral traction. The line of force misses the centre of resistance, causing an alignment error of \( \delta \) and initial angular displacement of \( \theta \).

Three different outer bow lengths are selected to test the effect that lengthening the outer bow has on initial angular displacement. The initial alignment error and the hook-target-to-tooth distance are kept constant.

Figure 54 shows that if the alignment error and positions of hook target and tooth remain constant, lengthening the outer bow will
decrease the angle between the hook target, the centre of resistance and the outer bow hook thus reducing the initial angular displacement.

![Diagram](image)

6 - alignment error  
A - hook target  
B1 - first outer bow hook position  
B2 - second outer bow hook position  
B3 - third outer bow hook position  
C - centre of resistance

**Fig. 54** Illustrates how lengthening the outer bow reduces the initial angular displacement (angle ACB) for a given alignment error (6) (angle ACB3 is greater than angle ACB2 which is greater than angle ACB1).

**GEOMETRIC ANALYSIS OF THE EFFECT OF REDUCING HOOK-TARGET-TO-OUTER-BOW-HOOK DISTANCE**

In the experiment illustrated in figure 55 the initial alignment error and the positions of the outer bow hook and the tooth are maintained. By moving the hook target closer to the outer bow hook the angle between the outer bow hook (B) the centre of resistance (C) and the hook target (A) will decrease. So will the initial angular displacement.
alignment error
A1 - first hook target position
A2 - second hook target position
A3 - third hook target position
B - outer bow hook position
C - centre of resistance

Fig. 55 Moving the hook target closer to the outer bow hook reduces the initial angular displacement for a given alignment error. Angle ACB measures initial angular displacement (angle $A_1CB$ is greater than angle $A_2CB$ which is greater than angle $A_3CB$).

RECOMMENDATIONS FOLLOWING EXPERIMENTS

1. Abandon the use of short outer bows, even where some molar uprighting is desired.
2. Keep the outer bows as long as practical.
3. Keep the hook target as close as practical to the outer bow hook.
4. Take great care to reduce the initial alignment error.

THE RELATIONSHIP BETWEEN MODELS AND LIVING TISSUES

These physical and geometric models, like teeth, are free bodies. They can move in response to a force and they do not have fixed axis. Depending on the direction and orientation of the force they can tip, translate or combine tipping and translation to varying degrees.
The wooden models differ from teeth in the nature of the resistance to movement. The resistance to movement in the model is frictional thus it is constant and predictable. The resistance to movement of teeth comes from biologic structures which allow movement by alteration in metabolism and by cellular response. The biologic response is complex. Usually it cannot be measured.

The type of movement of a tooth in response to an applied force can vary with

- the nature and amount of supporting structures
- the anatomy of the tooth's roots
- the tooth's relation to other teeth in the same arch
teeth which occlude with it.

Whatever the actual nature of the biologic response, if the tooth moves then the supporting structures will display a resistance to movement. Acceleration is never experienced.

This resistance is to tipping and to translation.

The degree of resistance of the supporting structures to tipping forces compared with the resistance to transulatory forces will determine the orientation of a tooth after a force is applied away from the centre of resistance.

The recommendations following experiments (page 59) will be invalid if a tooth's supporting structures would allow translation in preference to tipping. There would then be little likelihood of tipping during face-bow traction even if the line of force missed the centre of resistance.
PART IV

ALTERNATIVE FACE-BOW APPLIANCES
APPRAISAL OF FACE-BOW APPLIANCES IN CURRENT USE

Having reviewed the literature and conducted experiments relating to undesirable molar tipping the writer feels that a design of a face-bow appliance should permit:

1. The operator to keep the initial alignment error as small as possible.
2. The use of long outer bows.
3. The 'hook target' to lie as close as possible to the outer bow hook.
4. Delivery of a constant force.

These factors are amplified and illustrated in the following paragraphs.

1. Designs should allow the operator to keep the initial alignment error as small as possible.

If the line of action of the extraoral force does not coincide with the centre of resistance of the tooth under traction the result is an alignment error, which leads to tipping.

The alignment of two extraoral lines of force (between hook targets and face-bow hooks) with two intraoral, ill-defined points (the centres of resistance of the first molars) causes some difficulty in clinical practice.

The clinician must first estimate the locations of the molars' centres of resistance. This is subject to an error of perhaps 0.5 to 1 cm (between the bifurcation of the molars' roots and the midcrown areas). More error is likely to occur when the operator attempts to project the axis between the two centres of resistance extraorally so that he can register this axis with the extraoral lines of force. Perhaps some
Fig. 60 'Interlandi' appliance showing hook target midway between elastic band attachments.

Fig. 61 Calibrated force spring unit. Line of pull is ill-defined because the connector strap makes an angle with the spring unit.
pantographic mechanism would facilitate this task.

Two points are needed to describe the line of action of the extraoral force. These are (1) the point of connection of the force unit to the outer bow hook and (b) the point to which the hook will tend to move.

Point (a), the outer bow hook, is well defined in all available face-bow appliances. It is that point where the elastic band, strap hook or connector engages the metal hook on the end of the outer bow.

Point (b), the hook target, may or may not be easily recognised depending on the design and type of appliance.

The Gould appliance (see figure 14 on page 19) and the Interlandi appliance (figure 60 on facing page) both provide easily recognised hook targets. The line of extraoral force may not however be apparent when face-bow appliances are used with calibrated force spring units. This is illustrated in the photograph on facing page (figure 61).

With the 'Combination appliance' (figure 62 facing page 67) the operator must calculate the line of action of extraoral force by resolving headcap and neckstrap forces into a single line force vector. This can be done

(a) by calculation

(b) by template and headfilm

(c) by trial and error

as explained below.

(a) **By calculation**

To calculate the headcap and neckstrap forces which will give the
correct line of force resulting from the diverging lines of pull (headcap and neckstrap) the clinician needs to know:

(i) The angle that the headcap force makes with the occlusal plane

(ii) The angle that the neckstrap force makes with the occlusal plane

(iii) The direction that the resultant line of force should make with the occlusal plane

(iv) The total force to be placed on the outer bow hooks.

An example of the procedure for calculation is given in figure 63 on facing page and is as follows:

1. Draw the resultant line of force through the outer bow hook to the centre of resistance at the correct angle to the occlusal plane.

2. Draw lines from outer bow hook to represent the lines of force of the headcap and the neckstrap at correct angles to occlusal plane.

3. Mark off to scale on resultant line of force half the total force to be applied.


5. Read off headcap and neckstrap forces.

However, this calculation assumes a static head position. As the patient moves his head the headcap/neckstrap force ratio will vary. So will the resultant line of force. The patient's head position will be different when he is sitting, standing or sleeping (see figure 64 a, b and c on next page).
Fig. 62 Combination face-bow appliance

Headcap force - 45° to occlusal plane
Neckstrap force - 25° to occlusal plane
Resultant - 15° above occlusal plane
Total force to molars - 3lb.

Scale: 1in = 1lb.

Solution: Headcap force should be 1.6 lb, neckstrap force should be 0.9 lb.

Fig. 63 An example of the procedure for calculation of neckstrap and headcap forces with the combination face-bow appliance.
Fig. 64  Combination appliance. The effect of raising and lowering the head.
Headcap/Neckstrap forces:
Fig 64a 16oz/16oz, Fig 64b 16oz/31oz, Fig 64c 16oz/8oz.

When an appliance uses calibrated force springs (as does the combination appliance) there is difficulty in adjusting the straps to provide an exact force ratio. Holes in the connector strap have to be spaced lcm apart to allow easy coupling with the outer bow hooks. With the spring rate found suitable for these appliances, up or down one hole makes a difference of 1lb. 'Fine tuning' of the force direction is impossible.

Lastly, with the combination appliance, the balance of headcap to neckstrap force is upset when the tooth under traction tips, altering the position of the outer bow hook. If the force ratio is changed the direction of resultant force will be altered.

(b) By template and headfilm

Armstrong (1971) recommends the use of a headfilm with the activated appliance in place. He calculates the resultant line of force with a 'force vector protractor'. However this procedure involves an unnecessary exposure to radiation, so it cannot be recommended.

(c) Trial and error

McCrostie (1975) recommends adjustment of the incorrectly activated
'Combee' system by discontinuing the neckstrap or headcap (whichever has been over-activated) for a few days until tipping has been reduced. He also advocates adjustment of the outer bow to a 'slightly higher position' to aid correction of distal crown torque.

2. The design should permit the use of long outer bows

The combination appliance encourages the clinician to use short outer bows. Long outer bows (extending past the molars) cause the neckstrap and the headcap to exert pressure on the ears. This discomfort may affect the patient's co-operation:

![Combination appliance diagram](image)

*Fig. 65 Combination appliance with long outer bows causing headcap and neckstrap to exert pressure on the ears.*

The high pull headcap suffers the same disadvantage of interference with the ear unless the outer bow is bent markedly upward.
The Interlandi design limits the length of the outer bow by interposing the drawbar between the outer bow hook and the ear. Space has also to be allowed for the clinician to adjust the elastic band.

The Gould type of nylon headcap places the elastic hooks in front of the ear, again limiting the length of the outer bow.

3. The design should permit the hook target to lie as close as possible to the outer bow hook

All commercial face-bow appliances interpose force modules (elastic straps, springs and elastic bands) between the hook target and the outer bow hook. This unnecessarily increases the hook-target-to-outer-bow-hook distance and also may increase initial angular displacement.

For example,
- elastic neckstraps may have 15cm. between the back of the neck and the outer bow hook
- depending on the length of the outer bows, spring-type high-pull appliances have a hook-target-to-outer-bow-hook dimension of 9cm. - 12cm.
- elastic bands need 2cm. - 5cm. for activation.

4. The design of face-bow appliances should permit the delivery of a constant force

For the line of action of the extraoral force to be held in a constant relation with the tooth, the shape of the face-bow must stay the same.
**Fig. 9-11**

*Fig. 9b* From Thurow (1970) (p. 209) illustrates change in face-bow shape when force is increased.
Yet the shape of the face-bow will vary with the force applied to it (see figure 65 on facing page).

All face-bow appliances using elastic components will show force variation from day to day.

Those appliances using spring units show little force decay with time but the applied force may vary with changes in the position of the outer bow hook (as movement of dental structures occurs).

In summary, none of the face-bow appliances commercially available meet the writer's four basic criteria for minimising undesirable molar tipping.
DESIGN OF AN IMPROVED HEADGEAR

The writer proposes the following design (figure 66) to overcome the limitations of the face-bow appliances which are currently available from commercial suppliers:

![Diagram of headgear design](Image)

**Fig. 66** Prototype face-bow appliance designed by the writer. A flexible cord connects the face-bow to the force module, passing over a pulley to give a definite hook target. A drawbar supports the pulley, which can be moved up and down the drawbar. The force module is designed to supply constant force (by means of a figure-of-eight clock spring) despite differences in the position of the outer bow hook.
This design permits:

1. Simple visualisation of the line of force.

2. The use of outer bows in which the outer bow hooks extend 3cm - 4cm beyond the molar.

3. The outer bow hook to be as close to the hook target as the operator considers feasible. This would leave only the minimum space between the outer bow hook and the hook target which will permit distal movement of the outer bow hook as the tooth under traction moves.

The writer is now having a prototype of this design constructed for clinical testing of his conclusions on ways of minimising undesirable molar tipping during face-bow extraoral traction. It may also be used for experiments to establish values for the resistance ratio. This new design, as modified by clinical experience, may open a new era in headgear design for achieving controlled molar movement.
PART V

SUMMARY AND CONCLUSIONS
SUMMARY AND CONCLUSIONS

1. This treatise examines why the face-bow extraoral appliance sometimes causes molar tipping when clinicians are using the appliance to produce molar translation.

2. The literature is reviewed to ascertain
   (a) Various authors' views on how the appliance works.
   (b) What effects different adjustments will have on the action of the appliance.
   (c) What effects varying appliance designs will have on the type of molar movement caused by the appliance.
   (d) Whether the patient's facial type should influence the selection of the appliance and its adjustment.
   (e) Various authors' views on the causes of unintended molar tipping.

3. The action of the face-bow appliance can be summarised
   (a) Whether the face-bow appliance causes molar tipping or translation or a combination of both is determined by the relation of the line of action of extraoral force to the centre of resistance of the molar under traction.
   (b) The term 'hook target' is introduced to define a point to which the outer bow hook will move if it is free to do so. Thus the line of action of the force is from the outer bow hook to the hook target. The location of this hook target in a vertical plane determines what vertical components
of force (intrusive and extrusive) the appliance exerts on
the molar.

4. The process whereby the face-bow appliance initiates molar
tipping is well understood. It relates to the alignment of
the appliance.

However, despite the apparent simplicity of the problem
molar tipping is still experienced by clinicians using the
appliance to cause molar translation.

Further, the literature contains no detailed account of
clinical problems or design inadequacies which may contribute
to error in alignment.

5. The writer suggests that

(a) While the centre of resistance of a molar exists in a
limited area, its location is not precise.

(b) A clinical problem arises when two extraoral lines (of
force) have to be aligned with two ill-defined intraoral
points (centres of resistance).

(c) Some appliance designs do not permit the clinician to
visualise the lines of force easily.

6. During experiments with wooden and geometric models the writer
found that, by modifying the design of the appliance, the
clinician can take advantage of the fact that the moment causing
tipping changes as the tooth under traction tips.
7. From this evidence follow recommendations for reducing the amount of tipping during face-bow extraoral traction:

(a) Use a bow assembly which is as rigid as can be obtained

(b) Estimate as skillfully as possible the position of the centres of resistance of right and left molars (say 1cm above the centre of the buccal tube) and place marks on the patient's cheeks (extraorally) on both right and left sides which represent a continuation of the line between the estimated centres of resistance.

(c) Using a hook target as close to the ear as possible set the inner bow in position and adjust the outer bow so that the predetermined line of translation (between hook target and outer bow hook) passes through the marks defining the extraoral continuation of the two centres of resistance. A straight edge may be used for this purpose.

(d) It is suggested that the outer bow hook lies as close as possible to the hook target providing

(i) it is not so close that the line of force cannot be visualised

(ii) there is enough room for distal movement of the hook as treatment progresses.
8. These recommendations represent hypotheses which require clinical testing.

9. An appraisal of the face-bow appliances presently available suggests that many designs can themselves be causes of molar tipping.

10. A prototype face-bow appliance with a different anchorage unit and a different force module is proposed. This aims to eliminate many of the shortcomings found in current designs. This appliance should be useful for clinical testing of the recommendations in (7) above.


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