ORTHODONTIC AND BIOLOGICAL CONSIDERATIONS OF
DEGLUTITION, ORO-LINGUO-FACIAL MUSCLE FUNCTION,
AND TONGUE THRUST -
DIAGNOSIS

VOLUME II

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TONGUE THRUST, MALOCCLUSION, AND ASSOCIATED
OROFACIAL DISORDERS

4.1 Dento-Skeletal Associations

4.1.1 Malocclusion Types Associated with Tongue Thrust

According to Thurow (1977) the tongue provides an internal form for
the dental arch, and any aberration in its function or posture will be reflected
in the form of the dental arch. Graber (1972) stated categorically that
whatever the cause for a tongue habit (size, posture or function) it also serves
as an effective cause of malocclusion.

Most authors agree on the significance of tongue thrust in relation to
malocclusion (Pierce, 1978; Proffit and Mason, 1975; Hanson, 1979a; Subtelny
and Subtelny, 1973; Blyth, 1959; Andrews, 1960; Brauer and Holt, 1965). The
significance is that if the tongue thrust is not associated with a malocclusion
and/or a speech defect, then it does not require corrective therapy. Weiss and
Van Houten (1972) introduced the terminology "benign" and "detrimental" to
differentiate between a thrusting pattern which does not appear to be doing
any damage (benign) and one which is closely associated with malocclusion
and/or misarticulation (detrimental). Pierce (1978) points out that many
individuals have swallowed with a tongue thrust pattern all their lives and have
"never had any problems with teeth or speech". How closely related are
malocclusion and tongue thrust and what are the malocclusion types associated
with tongue thrust?
The incidence of tongue thrusting has been reported to be higher in patients with malocclusion than in those without malocclusion (Subtelny and Subtelny, 1973). A number of studies have found a strong relationship between tongue thrust and malocclusion. Rix (1946) studied the deglutition of 93 children between the ages of 7 and 11 3/4 years. The number of children swallowing with teeth in occlusion ("teeth shut") - equated with normal swallowing - was 61. Of this group, 36% had dentitions that "deviated from normal". The number of children swallowing with teeth separated ("teeth open") - equated with tongue thrust - was 27. Of this group, 81% had dentitions that "deviated from normal".

Again in 1948, Rix reported a study of another 100 children between 7 and 11 3/4 years. He found these children swallowed in one of two main ways: (a) a normal pattern (71%); and (b) a tongue thrust pattern (29%). He noted that it was among the 29% that a high concentration of "defects of the dental arches" were found. "In fact", he wrote, "defects of the position of teeth were more than twice as common in this group than in the 71% group."

Werlich (1962), according to Barrett and Hanson (1978), conducted a study in which he found that in those children with Class II, Division 1 malocclusions, 50.7% were tongue thrusters. Among those with Class I malocclusions, children in the oldest group included only 18.2% who were tongue thrusting; in the youngest group, where the incidence was highest, 32.6% were tongue thrusting. Among those children with open bite, 98.5% were tongue thrusters. Another significant relationship obtained was between posterior crossbite and tongue thrust. Of the youngest group, 68.2% were tongue thrusters, and 47.6% of the middle age group were thrusters.

Rogers (1961) compared a group of 497 orthodontic patients from his
practice with a group of 290 school students, serving as a normal population sample. The age range was from 5 to 12 years. Using what seems to be a valid method of determining tongue thrust, and using a double check system, he found that in the orthodontic patients 62.8% demonstrated a tongue thrust, of these he noted that 6% had a posterior tongue thrust. In the school children (normal population sample), 56.9% showed a tongue thrust and one showed a posterior tongue thrust (Fig.110). These high incidence figures agreed with findings of two other practices in Rogers' vicinity. He also found that a high percentage (68.9%) of the school children and 56.3% of the orthodontic patients who showed deep overbites also demonstrated a tongue thrust. These findings agreed with those of Rix (1953) and Straub (1961). Again, subjects with open bites showed a great tendency for tongue thrust, 98.2% from the normal population sample and 92.8% from the orthodontic patients. Of these figures Rogers commented, "these figures lend support to the premise that the tongue thrust is not only responsible for the original open bite condition but also may be the most potent factor in its recurrence after correction". Another figure of note was that 82.1% of school children (normal population) who appeared to have no need for orthodontic services also swallowed normally. Rogers noted, "this would seem to substantiate the theory that improper swallowing does disturb tooth position and normal dento-facial growth". Another factor of note, was the influence of the orthodontic treatment on the children in the orthodontic patients group. Rogers points out that the incidence of deep bite cases would have been higher except that orthodontic therapy had corrected the problem before the study was made. Thus the figure of 56.3% for tongue thrusters for this group is artificially low. Further, Rogers noted that the improved tooth position from orthodontic changes had eliminated the tongue thrust in some of the orthodontic patients used. He noted that some of the subjects exhibiting tongue thrust before treatment showed no thrusting towards the completion of their treatment when
Table 1. Tabulation of findings

<table>
<thead>
<tr>
<th></th>
<th>Normal population sample</th>
<th>Orthodontic patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongue-thrust during deglutition</td>
<td>165 of 290 (56.9%)</td>
<td>312 of 497 (62.8%)</td>
</tr>
<tr>
<td>Deep overbite cases showing tongue-thrust while swallowing</td>
<td>82 of 119 (69.0%)</td>
<td>156 of 277 (56.3%)</td>
</tr>
<tr>
<td>Patients showing grimace while swallowing, with no discernible tongue-thrust</td>
<td>11 of 290 (3.7%)</td>
<td>46 of 497 (9.3%)</td>
</tr>
<tr>
<td>Patients showing a tongue-thrust while swallowing, with no grimace</td>
<td>3 of 290 (1%)</td>
<td>8 of 497 (4.6%)</td>
</tr>
<tr>
<td>Class II deep overbite cases showing abnormal swallowing</td>
<td>63 of 70 (90.0%)</td>
<td>98 of 150 (65.3%)</td>
</tr>
<tr>
<td>Open-bite cases showing abnormal swallowing</td>
<td>55 of 50 (90.0%)</td>
<td>78 of 84 (92.8%)</td>
</tr>
<tr>
<td>School pupils examined needing no orthodontic treatment</td>
<td>112 of 290 (38.6%)</td>
<td>No data</td>
</tr>
<tr>
<td>School pupils not needing orthodontic treatment and showing a normal swallow</td>
<td>92 of 112 (82.1%)</td>
<td>No data</td>
</tr>
<tr>
<td>Completely breast-fed children showing normal swallowing</td>
<td>2 of 4 (50%)</td>
<td>No data</td>
</tr>
</tbody>
</table>

Fig. 110 Table: Tongue thrust and malocclusion. (Rogers, 1961)

Fig. 111 Tongue thrust and open bite. (Angle, 1907)
the overbite and overjet had been corrected and no specific therapy to correct the tongue thrust was initiated. Therefore again the figure of 62.8% for this group could be artificially low.

Barrett and Hanson (1978) make reference to several other studies that have found similarly high incidences between tongue thrust and malocclusions, "that a significant relationship exists between tongue thrust and malocclusion seems to be quite well documented". Moller (1976) also noted that, based on "statistical coincidence", specific patterns of muscle activity during mastication and swallowing have been related to morphology and occlusion. Moss (1975) asserted that patients with normal occlusion show a typical pattern of muscle activity, and patients with malocclusions demonstrate muscle patterns differing from those of normal subjects. He found that subjects with Class II, Division 1; Class II, Division 2; Class III and postural Class III malocclusions can be differentiated on the basis of their patterns of muscle activity.

Angle (1907) was one of the earliest authors to write on the association of tongue thrust and malocclusion. Using one example (Fig.111) to illustrate the effect of tongue thrust, he observed that "the pressure upon the incisal edge prevents full eruption and holds the teeth in infra occlusion, while the molars, being held apart much of the time, lengthen into positions of supra-occlusion from lack of resistance". He also noted that there were many possible variations in the tongue thrust "habit", and consequently many variations in the malocclusions found.

Perhaps the best way to view the malocclusion types associated with tongue thrust is to review the classifications of tongue thrust. As discussed in an earlier section, most authors classifying tongue thrusts have related the
tongue activity to its associated oral deformity (Gwynne-Evans and Tulley, 1956; Straub, 1961; Brauer and Holt, 1965; Garliner, 1971; Barrett and Hanson, 1978). The classification of Barrett and Hanson (1978) (described previously) being the most comprehensive, seems to be the most applicable (Fig. 89). The twenty two illustrations in figures (Figs. 90-103) show vividly the many types of malocclusions associated with tongue thrust.

Briefly reviewing these, it is found that in:

**Type 1**, there is a Class I occlusion with possible crossbite, an overjet of the maxillary incisors, with the lower incisors moderately retruded. **Subtype /1s/** shows relatively normal upper incisors but excessively retruded and often overerupted lower incisors.

**Type 2**, there is a Class II, Division 1 occlusion; there is marked labioversion of the upper anteriors, and the lower anteriors are retroclined and "classically in a jumbled but direct line from cusp to cusp". **Subtype /2s/** has an accompanying anterior open bite.

**Type 3**, there is a Class III occlusion "usually in the absence of true prognathism", possible unilateral crossbite; upper incisors relatively normal, lower incisors protrusive and may display spacing. **Subtype /3s/** has an anterior open bite.

**Type 4**, the occlusion is Class I; the incisors both uppers and lowers are in labioversion, often with some spacing of the lowers. **Subtype /4s/**, shows a Class II, Division 1 occlusion.

**Type 5**, the occlusion is Class I; there is normal anteroposterior relation of the incisors but uppers and lowers are undererupted with incisal edges parallel when the molars are in occlusion. **Subtype /5s/**, is more circumscribed and constricted with molars usually tipped linguually; the incisal edges "form a well-defined oval when molars are occluded".

**Type 6**, the occlusion is Class I; the incisors are in a relatively normal
relationship with slight overjet, both uppers and lowers may be overerupted forming a deep overbite. **Subtype /6s/**, is based on a Class II, Division I malocclusion, the whole lower arch being constricted.

**Type 7**, the occlusion is Class I and there may be a crossbite on the side opposite the tongue thrust; the anterior dental relationships show normal central incisors, but the lateral incisors, canines and first premolars on one side only are undererupted displaying a unilateral open bite. **Subtype /7s/**, the differentiating characteristics are that the unilateral open bite is distal to the basic type with more posterior teeth in open bite and more anterior teeth in normal occlusion.

**Type 8**, usually there is a Class III occlusion although there may be a Class I occlusion in younger patients; there is a bilateral open bite in the molar region; the incisors are in normal relationship, although slight retrusion of the uppers may be evident. **Subtype /8s/**, here there is a Class II, Division 2 malocclusion and the bilateral open bite is less pronounced. Here the incisors are frequently overerupted, resulting in a deep anterior overbite.

In a study of 1,000 consecutive tongue thrust cases, Barrett (as quoted by Barrett and Hanson, 1978) recorded the relative incidence of the various types (Fig. I12). These figures, although not a true reflection of the incidence in the general population since they are those cases actually referred by dental practitioners, give a rough guide as to the frequency of occurrence. It is possible that Type 1 cases are more common, but since they are less deforming, may be accepted by the patients, also Type 7 and Type 8 may not be diagnosed as being associated with a tongue thrust. Hanson (1979a) in reviewing this study pointed out that the most common malocclusion was an overjet found in Types 1 and 2. These two patterns together accounted for about 75% of the 1,000 subjects. The next most common anterior malocclusion found was an open bite, occurring in 8.9% of the subjects. The Type 5
Table: Relative incidence of tongue thrust types in 1000 cases.
(Barrett and Hanson, 1978)

<table>
<thead>
<tr>
<th>Swallowing pattern</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1. Incisal thrust</td>
<td>217</td>
<td>21.7</td>
</tr>
<tr>
<td>Type 2. Full thrust</td>
<td>521</td>
<td>52.1</td>
</tr>
<tr>
<td>Type 3. Mandibular thrust</td>
<td>18</td>
<td>1.8</td>
</tr>
<tr>
<td>Type 4. Bimaxillary thrust</td>
<td>46</td>
<td>4.6</td>
</tr>
<tr>
<td>Type 5. Open bite</td>
<td>89</td>
<td>8.9</td>
</tr>
<tr>
<td>Type 6. Closed bite</td>
<td>57</td>
<td>5.7</td>
</tr>
<tr>
<td>Type 7. Unilateral thrust</td>
<td>13</td>
<td>1.3</td>
</tr>
<tr>
<td>Type 8. Bilateral thrust</td>
<td>39</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Fig. 112

Table: Malocclusion frequencies in the different groups of children

(Melsen et al., 1979)
pattern, associated with a "closed bite" was found in 5.7% of Barrett's patients. Hanson refers to other researchers (unnamed) who have found that approximately 80% of patients with "closed bite" have a tongue thrust, adding that it is difficult to detect because of the "double wall of teeth" which block the examiner's view when the teeth are in occlusion. He then suggests that if there are no diastemata to "peek through", it may be necessary to "hold the bite open with a tongue depressor" when checking for tongue thrust as these patients swallow. The Type 8, bilateral thrust, he observes, "fortunately" occurs in only about 4% of the patients referred to him, adding that this thrust is the most difficult to correct.

It is interesting to compare the study of Walther (1964). He studied the muscle behaviour of 375 patients attending an orthodontic clinic, and showed that tongue thrust was about as common in Class I malocclusion as it was in Class II, Division 1. Tongue thrust was also found in 17% of the patients with Class III malocclusion. These results tend to support the findings and classification of Barrett and Hanson (1978) above.

In essence then, it appears that tongue thrust is associated with cases of open bite, both anteriorly and posteriorly, and unilaterally and bilaterally; with cases of deep overbite; and with cases involving constriction of the dental arches. Graber (1972) related the tongue thrust behaviour to the "balance" of forces operating in and around the oral cavity. He noted that "whether the abnormal tongue activity is the result of a compensatory response to an abnormal morphogenetic pattern or is retained from the infantile 'visceral swallow', the balance between outside and inside forces may be disturbed, accentuating maxillary incisor protrusion, creating an open bite tendency and fostering a narrowing of the maxillary arch" (discussed later).

A recent study conducted by Melsen, Stensgaard, and Pedersen (1979)
related the type of swallow with the frequency of single malocclusion symptoms (Fig. 113). Compared to the group of children with normal swallowing, children with tongue thrust and those with teeth apart swallow had an increased frequency of "distal occlusion", extreme maxillary overjet and open bite. However, their results did differ from other studies regarding deep overbite. They found that "the frequency of deep bite was not affected by teeth-apart swallow, but was decreased in cases of tongue thrust swallow".

A study conducted by Hanson, Barnard, and Case (1970) into the various types of malocclusion and palatal arch dimensions of tongue thrusters compared to children with normal swallows, found that the only factors to vary significantly between the groups were overbite, open bite, and lingual crossbite.

The tongue thrust classification of Brauer and Holt (1965) (mentioned previously) was the outcome of a survey conducted by them. This classification was based on the "resulting deformity observed", although perhaps it was probably more correct to say the 'associated' deformity observed. In contrast to the classification of Barrett and Hanson (1978), instead of an Angle's classification basis, it was simply related to the deformity (malocclusion) present, either anteriorly, laterally, or both anteriorly and laterally (Fig. 114). The actual deformities or malocclusions then seen in the various types were again: open bite, "procumbency of anterior teeth", i.e. bimaxillary protrusion, deep overbite, and posterior crossbite.

Again, the eight types of malocclusion associated with tongue thrust according to Garliner (1971) show the same kind of relationships. However, the aspect of crossbite is an obvious omission from this classification, and contrasts with the other authors.
Tongue Thrust Classification

TYPE I - Nondeforming Tongue Thrust

TYPE II - Deforming Anterior Tongue Thrust
Subgroup 1 - Anterior Open Bite
Subgroup 2 - Associated proclivity of Anterior Teeth
Subgroup 3 - Associated Posterior Crossbite

TYPE III - Deforming Lateral Tongue Thrust
Subgroup 1 - Posterior Open Bite
Subgroup 2 - Posterior Crossbite
Subgroup 3 - Deep Overbite

TYPE IV - Deforming Anterior and Lateral Tongue Thrust
Subgroup 1 - Anterior and Posterior Open Bite
Subgroup 2 - Associated proclivity of Anterior Teeth
Subgroup 3 - Associated Posterior Crossbite

Fig. 114 Table: Nondeforming/deforming tongue thrust classification. (Brauer and Holt, 1965)

Fig. 115 Anterior open bite due to a tongue thrust with a "tooth-together" swallow and competent lips. (Hovell, 1955)
A brief overview of authors' observations on these main malocclusion types follows.

4.1.1.1 Open Bite: (both anterior and posterior are viewed together)

Baker (1954) reported that in most cases, anterior open bites appeared to be caused by the tongue thrust that occurs during deglutition. Hovell (1955) described how he believed that the tongue thrusting anteriorly with the teeth together produced an anterior open bite. The upper anterior teeth are moved anteriorly and prevented from erupting fully, while the lower incisors although not being moved anteriorly are prevented from erupting by the tongue action thrusting forward above them. If lip posture is normal, he noted, the lower lip lies in front of the upper incisors preventing them from moving forward. "In such a case there is a considerable degree of anterior open bite with little increase in overjet" (Fig.115). Leech (1958) found that 4% of his 500 subjects had anterior open bites. All were tongue thrusters. Of note is the reference to the association of non-nutritive sucking (seen in a later section) to anterior open bite and tongue thrust. Over half of the 4% sucked a "dummy" or thumb. Jann (1960) postulated that tongue thrusting in children has a direct causal relationship with open bite. Straub (1961) drew attention to what he saw as tongue behaviour patterns on skeletal structures causing open bite (more is discussed in a later section). Subtelny and Sakuda (1964) described three general etiological factors associated with open bite. The second factor, apart from vertical growth deficiencies and thumb and finger sucking habits, had to do with the tongue, included in the heading of "disproportionate muscle growth or aberrant muscle function". They noted that the "enlarged, excessively fronted, or protrusive function of the tongue is thought to prevent the full eruption of anterior dental units or to exert a disfiguring influence on the moulding of the anterior dentoalveolar processes". These authors did make mention of the possible transience of this association, since with age the
disproportionately large tongue and its resultant posture which could be causing and maintaining an open bite for a number of years, could give way to adequate growth of the jaws, thus equalising the proportions and allowing the open bite to close. However, adequate growth must take place before the tongue can be accommodated. Tulley (1964a) found there was a high incidence of open bite and "incomplete overbite" in a group of tongue thrusters with malocclusions requiring treatment compared to a sample of tongue thrusters of the normal population. Gershater (1972) found a high incidence of open bite malocclusion (32.3%) among the children who were both mentally and emotionally disturbed. This was mainly attributed to their generally "poor neuro-muscular patterns" and "pernicious oral habits". Practically all these cases showed some degree of tongue thrusting. In a cinefluorographic study of tongue thrusting patterns and incisor relationships, Massengill, Quinn, Hall, and Boyd (1974) found in one type of case that the tongue moved downward instead of upward, with the tip of the tongue "dragging on the lower central incisors". This action was believed to be responsible for the open bite malocclusions observed (Figs.116A-C). If the tongue did not drag on the lower incisors, meaning exerting a downward and possibly lingual force, it was found to rest in that position for most of the swallowing cycle. Barber and Bonus (1975) while conducting research into lip strength measurements in tongue-thrusting and non-tongue-thrusting subjects, found there were "significant initial differences in the dental relationships between the tongue-thrusting groups and the normal, non-tongue-thrusting group". The malocclusions associated with the tongue thrusters were characterised by "an anterior open bite, diastemata between the maxillary and mandibular anterior teeth, and incompetent lips, or a combination of these conditions". Proffit and Mason (1975) emphasised the resting posture of the tongue in tongue thrusters as being likely to cause anterior open bite malocclusions. "It is quite possible", they said, "that light forces produced by an anteriorly positioned tongue tip can impede eruption of
Fig. 116A Case: Anterior open bite (frontal view)

Fig. 116B Case: Anterior open bite (lateral view)
Fig. 116C Case: Anterior open bite, tongue tip was observed to move downward and rest against the lower central incisors. (Massengill et al., 1974)

Fig. 117 Posterior open bite - tongue position. The tongue resting between the teeth can inhibit eruption of the teeth in one arch (A) or both (B), causing an open bite in the affected area. (Thurow, 1977)
incisors. If, at the same time, there were no impediment to posterior eruption, an open bite would result as the posterior teeth erupted and the anterior teeth did not. They pointed out that in a growing child, continuous eruption of both anterior and posterior teeth is necessary to compensate for vertical growth of the face and jaws. Thus, if the anterior teeth are prevented from achieving full eruption while the posterior teeth are able to erupt fully a well circumscribed anterior open bite is likely to result (Fig. 98). Begg and Kesling (1977) also have noted this association of tongue thrust with "the inability of the anterior teeth to occlude" causing an anterior open bite. Thurow (1977) described the process by which a posterior open bite could occur (Fig. 117), and contended that a similar deviation can occur anteriorly, "where the effects are much more obvious" (Fig.118). Thurow said that the tongue may either rest between the teeth or thrust between them during swallowing, as a result of being a "mere habit, as is often assumed", or it may be "an accommodation to anatomic disharmony". On the latter point he meant that if the tongue is too large or the airway too small, the interdental position may be "the only one compatible with comfort or even with life". He also claimed that the tongue is the most common local cause of anterior open bite. Weber (1980) is one more recent author describing the effect of tongue thrust on the anterior dentition with a resulting open bite (Fig.119). In this case the posterior occlusion is intact while protrusion of the maxillary incisors, spacing between the anterior teeth and anterior open bite are evident.

4.1.1.2 Crossbite

Rix (1948) found that "the most common defect" associated with the tongue thrusters he studied was a small upper arch. He described it as being "often narrow relative to the lower and the buccal cusps of the upper cheek teeth articulate on one or both sides internal to the buccal cusps of the lower cheek teeth". The palatal vault he found to be high, and there was
Fig. 118  Anterior open bite - tongue position.  (Thurow, 1977)

Fig. 119  Tongue thrust, anterior open bite, and incisor protrusion.  (Weber, 1980)
irregularity of the six upper anterior teeth. As a note on lip function he found that when the lips are habitually kept closed the upper incisors tended to be crowded and rotated. When a lip seal was absent he found that the incisors tended toward some degree of labio-inclination with a concomitant decrease in crowding (Fig. 120). Hanson, Barnard, and Case (1970a) as mentioned previously, found "lingual crossbite to be one of three characteristics significantly associated with tongue thrusting, the others being overbite, and open bite". They postulated that lingual crossbite possibly promotes thrusting by forcing a narrowing of the tongue, thereby increasing its length. Graber (1972) observed that in some instances, as the tongue thrusts forward constantly, increasing the overjet and open bite, the peripheral sections no longer lie over the lingual cusps of the buccal segments. Posterior teeth erupt and gradually eliminate the interocclusal clearance, "the postural resting vertical dimension and occlusal vertical dimension become one and the same, with the posterior teeth in contact at all times". Graber described this as not being a dentally healthy situation. One side-effect of this he suggested may be bruxism; another is the bilateral narrowing of the maxillary arch as the tongue drops lower in the mouth, providing less support for the maxillary arch. Clinically, he said, this may be observed as a unilateral crossbite, with a convenience swing to one side or the other as the mandible is moved laterally under the influence of tooth guidance. Similarly Thurow (1977) noted that "if the tongue lies low or high in the buccal segment (Fig. 121), the affected arch will be overexpanded in relation to its opposing arch, which in turn will tend to be narrower because of deficient support". Various forms of buccolingual crossbite are the result. However, he pointed out that this is a complex area and simple explanations must be viewed with caution. Many anatomic variations throughout the head, he stressed, can alter the support and posture of the tongue with superficially similar effects.
Fig. 120  Incisor relations - lip seal absent.  (Rix, 1948)

Fig. 121  High (A) or low (B) tongue position will overexpand one arch and allow narrowing of the other.  (Thurow, 1977)
4.1.1.3 Bimaxillary Protrusion

Hovell (1955) observed that a large tongue, or one which is positioned forward due to the skeletal pattern, will cause double proclination of the incisor teeth, often with spacing. The buccal segments tend to "drift forward and a bimaxillary dento-alveolar prognathism results" (Fig.122). Hovell also pointed out that this is the result of soft tissue patterning and is a racial characteristic in some ethnic groups. Straub (1961) noted how a bimaxillary protrusion could be produced by "constant tongue action". A case he presents (Fig. 87) shows the effects of a "severe abnormal swallowing habit". Here he claims that the whole facial profile is forced into a complete bimaxillary protrusion, "both the upper and lower teeth were pushed forward by the tongue until there was a complete displacement of tooth and bone". It was precisely such a case as this which first aroused the author's interest in this field of study (Fig.123). Graber (1972) displayed a very similar case (Fig.124) in which he believed that macroglossia was the causative influence. Again Barber and Bonus (1975), in their study of thirty-two tongue thrusting children, observed open bites, diastemata between the maxillary and mandibular anterior teeth (bimaxillary protrusion), and incompetent lips to be characteristic of these subjects.

4.1.1.4 Deep Overbite (incl. Class II, Division 2)

Hovell (1955) found cases of "tooth apart" swallows where there was excessive contraction of the lips and cheeks. The action on the teeth was to produce a gross retroclination of upper and lower incisor teeth, "their faulty axial inclinations result in an excessive incisor overlap, which is greater if the arch relationship is postnormal". He noted that even when lip posture was incompetent, the lips were usually brought together during swallowing, so that it was not uncommon to see upper incisors grossly retroclined and yet almost
Fig. 122  Radiograph: bimaxillary dentoalveolar prognathism and incisor proclination. (Hovell, 1955)
Fig. 123  Case JWS: Front and profile - bimaxillary protrusion, tongue thrust. (Abbott, 1975)
Fig. 124  Malocclusion (bimaxillary protrusion) resulting from a condition of macroglossia.  (Graber, 1972)

Fig. 125  Schoolchildren with deep overbite, but forward tongue thrust in speech and swallowing.  Note lowering of mandible.  (Tulley, 1964a)
completely exposed when the lips were in their resting position. Ballard (1953) noted that increased overbite could be affected by tongue thrusting behaviour. Tullity (1964a) also noted this phenomenon although he found it to be a rare occurrence (Fig. 125). Massengill, Quinn, Hall, and Boyd (1974) however, found it to be far more common, in that the swallowing pattern found in a case such as Fig. (126) of a Class II, Division 2 type case, was found in 27 out of 30 patients with tongue thrusting. Begg and Kesling (1977) also note the presence of a deep overbite in some cases, where the "jaws move apart, thus allowing the tongue to be thrust forward between the teeth", i.e. outside the arches. Thurow (1977) seems to have explained this entity most graphically (Fig.127). He describes how the tongue may rest between the buccal teeth instead of inside them and so apply an apical vector impeding their eruption, and that "this can occur either independently or in combination with any of the other deviations". If all the buccal teeth are subject to this influence, he proposed, the mandible can then close further than normal, allowing the anterior teeth to overclose. He added that on clinical examination this gives the illusion that the anterior teeth have overerupted even though the problem is actually retarded buccal eruption.

4.1.1.5 Class II, Division 1

Ballard (1953) believed that tongue thrust was the etiological factor in "a high percentage of these cases". He suggested that it was "probably correct" to say that the most important factor associated with a "Class II, Division 1 dento-alveolar abnormality in orthodontics in England" was the tongue thrust swallowing pattern. He described how in the tongue thruster the tongue is moved forward between the incisor teeth and "usually against the upper incisors and over the lowers". This thrust is balanced, he said, by a contraction of the lower lip, as is evidenced "most markedly" by the contraction of the mentalis muscle. The tip of the tongue labially inclines the
Fig. 126  Class II, Division 2 malocclusion with tongue thrust. (Massengill et al., 1974)

Fig. 127  (A and B) Buccal tongue thrust, retarded buccal eruption, deep overbite anteriorly. (Thurow, 1977)
upper labial segment, and the contraction of the lower lip against the tongue thrust lingually inclines the lower labial segment. The effect, he said, of this "abnormal swallow" is to produce a degree of increased overbite and/or overjet, the variations being in relation to other factors in the case. Hovell (1955) described two instances where a Class II, Division 1 malocclusion is related to tongue thrust. Firstly, where there is an anterior tongue thrust with teeth together, if the lips are incompetent, proclination of the incisors can result. When there is severe incompetence of the lips, "the less effect they have in preventing proclination of the upper incisors by the tongue". He described then how the lower lip comes to lie behind and contracts behind the upper incisors, "because it cannot get in front of them", and the full force of its contraction comes upon the lowers which are retroclined. The final incisor relationship produced is that of an Angle Class II, Division 1 malocclusion with proclined upper and retroclined lower incisors. Secondly, in the tooth apart swallow with tongue thrust, the anterior open bite can be less marked, even non-existent, because separation of the jaws allows room for the tongue to be protruded without impeding the eruption of the incisors (Fig.128). The effects upon the axial inclination of the incisor teeth are the same, with an increased tendency to the production of the Class II, Division 1 incisor relationship. This, he said, is because the parting of the jaws increases the likelihood of incompetence of the lips during swallowing.

In comparison to Hovell's first observation, according to Gwynne-Evans and Tulley (1956), an overjet of the upper incisors may be present, "particularly if there is a tendency toward a postnormal relationship of the jaws coupled with a swallowing pattern in which the lower incisors are held back by the contracting lower lip while the tongue thrusts forward over them against the upper incisors". This description then, is of a Class II, Division 1 malocclusion.
Fig. 128  Deep overbite: "tooth-apart" tongue thrust and incompetent lips. (Hovell, 1955)
Rix (1948) distinguished between Class II relationships that exhibited either "broad, ample arches" or "crowded and irregular arches". He found that when crowded and irregular arches "are seen associated with an Angle's Class II relationship it is usual to find that the swallow is of the infantile pattern" i.e. a tongue thrust swallow.

Tulley (1964a), in an analysis of occlusal abnormalities in 71 cases with adverse tongue and lip behaviour found an "expectedly high number of Angle's Class II, Division 1 malocclusions". He found: Class I, 10 cases; Class II, Division 1, 43 cases; Class II, Division 2, 7 cases; and Class III, 11 cases.

That the tongue is a powerful muscle complex capable of causing dental deformation was acknowledged by Kortsch (1965). He found that 20.3% of 660 primary school pupils manifested a tongue thrust. Of the thrusters, 44.8% had a Class II malocclusion. This significantly exceeded the 24.5% incidence of Class II malocclusions in the entire school population. Kortsch presented other data concerning other types of malocclusion and concluded that his statistics indicated that the tongue, aside from causing anterior open bites, is implicated in the development of Class II malocclusion.

Tulley (1969) again made reference to previous work by him, this time with a different slant. Prefacing his findings with the remark that, "by far the most common reference on tongue-thrusting is associated with Class II, Division 1 malocclusion", he reported that 22% (329) of his total sample of 1,500 11-year-old school children showed some degree of this malocclusion. However, he then went on to discriminate between those cases with a Class II, Division 1 malocclusion whom he assessed as requiring orthodontic treatment and those whom he assessed did not (less than half). Unfortunately his method of assessment was not explained and thus could be interpreted as being too
subjective for these figures to be reliable. Tulley also found that "only 43 of the 329 children showed evidence of adverse tongue and lip behaviour which might jeopardise permanent correction of the incisor relationship". However, the explanation of the method by which he was able to establish this prognosis was not stated and therefore once again these figures at best could be regarded as a rough guide.

Massengill, Quinn, Hall, and Boyd (1974) found that in a study of 30 patients with tongue thrust, 27 had a similar pattern of swallowing. However 3 exhibited a lingual pattern "of the tongue moving downward instead of upward and, to a degree, the tip of the tongue dragging on the lower central incisors". A Class II, Division 1 case was presented as being caused by this type of lingual pattern (Fig. 116B).

On a more extreme note, Fletcher (1981) contended that difficulty in performing the act of swallowing is found almost exclusively in patients with Class II, Division 1 malocclusions. According to this author some of these patients, notably those with marked Skeletal II dental base relationships and increased lower face height, with associated large overjets and decreased overbites, together with an inability to comfortably approximate the lips, find it difficult to swallow in the typical manner. "They are unable, with these anatomical handicaps, to seal off the front of the mouth, so that the oral fluids can be expelled, without embarrassment, in the appropriate direction." Fletcher stressed the attaining of an oral seal as being the cause of the malocclusion, "one way by which they overcome their problem is to reflexly move the tongue forward over the lower incisors and against the lower lip, so making an anterior oral seal when swallowing". Importantly, Fletcher draws a distinction between Class II, Division 1 and Class II, Division 2 with respect to tongue and lip function, saying that Class II, Division 2 malocclusions are
associated with "plentiful lip tissue with which to create the necessary oral seal". Thus these patients, he says, have no reason to use the tongue to assist in forming an anterior oral seal.

4.1.1.6 Class III

In contrast to Class II, Division 1 cases, there is very little mention made in the literature of tongue thrust associated with Class III malocclusions. Rix (1948) found that children with an Angle's Class III relationship "invariably fail to put their teeth together when they swallow", meaning that they exhibited some form of tongue thrust. He demonstrated this finding with cases of identical twins aged over 13 years with Class III malocclusions, no family history of this type of malocclusion, small maxillary arches compared to the mandibular arches, and who both "retained an infantile mode of swallowing".

It was Straub (1961) who, after hesitating for many years to go on record as implicating tongue thrust in the "etiology of Class III malocclusion", came out strongly in identifying tongue thrust as a causative factor; "the abnormal swallowing habit is definitely one of the causes of some of our severe Class III malocclusions." Backing up his argument with the findings of other orthodontists in his area who had studied the causes of this malocclusion and had found there was a definite correlation between abnormal swallowing and Class III malocclusion, he described the processes involved. He related the mechanics involved in abnormal swallowing to the collapse of the buccal and anterior segments in cases of crossbite with blocked-out upper canines and lateral incisors, suggesting then that the relationship between abnormal swallowing and Class III malocclusion became apparent to close observers of this problem.
Straub claimed that abnormal swallowing caused a complete collapse of the maxilla, and adverse growth of the mandible was caused by "the masticating pressure of a complete crossbite on the upper jaw." Two other associated factors he described were: (1) a narrow palate, and (2) an enlarged tongue. He suggested that many children who have "never learned to swallow properly" never put their tongues against their palates, the result being a palate so narrow "that it is mechanically impossible to place the tongue against it". Also he suggested that in Class III malocclusion the tongue is usually enlarged "as a result of the position in which it is placed in abnormal swallowing". Citing an example of a severe Class III case he described how, with changes to the occlusion and to the function of the tongue, the severe Class III was corrected and normal swallowing was achieved with the tongue returning to normal size and normal linguopalatal contact re-established.

Tulley (1964a) analysed a number of cases requiring orthodontic treatment who demonstrated adverse tongue and lip behaviour. Out of 71 cases, 11 were Class III which was the second highest incidence after Class II, Division 1 with 43.

According to Garliner (1971) tongue thrust contributes to both the pseudo-Class III relationship, by moving the lower teeth labially with the force of the abnormal swallow; and to the skeletal Class III problem, by finding free space within the skeletal elongation.

He described how the pseudo-Class III occlusal problem was caused by factors other than skeletal, tongue thrust being one. "If the oro-facial muscles are in an imbalanced state, with the tongue, in swallowing, pushing against the lower incisors, the dentition will move into a Class III relationship" (Fig.129). As far as the skeletal Class III went, this was a different picture. He described
Fig. 129  Pseudo-Class III and tongue thrust.  (Garliner, 1971)
how the tongue can push against the lower dentition during swallowing due to the extra amount of room created by the discrepancy between upper and lower arches. He also warned of the danger of correcting the jaw relationship surgically without correcting the tongue thrust, producing two examples showing a pseudo-Class III and an open bite which were post-operative sequelae of not correcting the tongue thrust.

In a similar way Barrett and Hanson (1978) described two types of tongue thrust associated with Class III malocclusions, calling the tongue action a "mandibular thrust". The first, or Type 3 in their classification, described the pseudo or "functional" Class III case (Fig. 94). Here they found that the thrust splayed the lower teeth as well as forcing the mandible forward. However, there is usually no true prognathism and usually no bilateral crossbite with the infrequent occurrence of a unilateral crossbite. They hasten to add that the Class III occlusion accompanying a bilateral crossbite would indicate "aberrant growth pattern, true macroglossia, etc. rather than tongue thrust and is thus called true Class III". In describing their Subtype /3s/ (Fig. 95) which is characterised by an anterior open bite, they describe the tongue action as being "spread between the incisal edges in contact with the upper lip". This varies with the Type 3 in that there the tongue apex is described as being "thrust against the lower incisors or symphysis of the mandible".

4.1.1.7 Controversial Aspects of the Tongue's Causal Association in Malocclusion

So far, this discussion has concerned itself with the association of tongue thrusting with malocclusion. It is obvious that some authors are convinced of the direct causal nature of tongue thrust on the occlusion producing various malocclusions. However, there is a body of evidence to
support the view of some authors that the tongue thrust is more of an adaptive response to the malocclusion and not a direct causal factor.

Those against tongue thrust being a causal factor:

Tulley (1964b) claimed that his research had shown him that "provided the facial skeleton is harmonious and the soft tissue shape and size is within the normal limits" a tongue thrust has "little or no lasting effect on the dental arches". He used the findings of Tulley (1952), Ballard (1962), Rogers (1961), Subtelny and Subtelny (1962), Hopkin and McEwen (1957), "and many others" to back up this claim. He proposed that the mandible "is merely lowered to permit the forward tongue movement".

It was also suggested by Subtelny and Sakuda (1966) that the pattern of tongue function during swallowing is frequently an adaptation to the surrounding skeletal and dental environment. Going further, they proposed that this adaptation indicated that a correction in dental arch form and dental arch relationships, with all factors being equal, will frequently result in a "concomitant adaptation of tongue and lip activity".

A study conducted by Milne and Cleall (1970) suggested that the presence of a tongue thrust "may not necessarily be detrimental to the occlusion." They proposed that the "physiologic tongue thrust" might be used in those instances where it is considered that the tongue is merely adapting to the environment.

In a study performed by Subtelny and Subtelny (1973) it was found that the fundamental aspects of the process of swallowing were basically the same in the different individuals with differing dento-skeletal environments. They found that during the early stages of swallowing, regardless of the
configuration of the oral environment, all of their malocclusion subjects moved the tip of the tongue toward the lingual aspect of the maxillary incisors and its "contiguous alveolar tissue".

When variations in swallowing were observed by the authors in patients with differing types of dentoskeletal configurations, they were seen in the anterior region of the oral cavity. "The varying patterns of tongue movement seemed to functionally adapt to the variations in the configuration of the anterior malocclusion" (Fig. 130).

Subtelny and Subtelny then went on to describe the tongue tip position in swallowing for three malocclusion types - maxillary protrusion (Class II, Division 1), maxillary deficiency (Class III), and open bite malocclusions. These descriptions are basically the same as those previously mentioned in this section. The different aspect of the findings of Subtelny and Subtelny was in their interpretation. They found that "appreciable differences in tongue-tip function during swallowing were identified with differences in the contiguous dentoskeletal form". They interpreted that the tongue was "functionally adapting" to the specific anterior oral environment to achieve a seal during swallowing.

Furthermore, they concluded that from all indications the functional movements of the orofacial musculature structures were adapting to the variables of the form of the adjacent oral environment. "The basic pattern of function, once the tongue-tip adapted to its contiguous environment, was the same in all of the subjects studied." Thus they suggested that protrusive tongue activity could be a functional adaptation to its environment.

Proffit and Mason (1975) related the incidence of open bite and incisor
Fig. 130  Tongue tip activity and anterior dental environment. (Subtelny and Subtelny, 1973)
protrusion to tongue thrusting. On the subject of open bite it was revealed that the statistics used (United States Public Health Service, 1973) showed a higher incidence of tongue thrust (about 10%) than for open bite malocclusions (3.9% of white children aged 6 to 11 years). However, the 10% figure included thumb-suckers, and these authors do not specify if the black population is included as it was for open bite (16.3% compared with 3.9% for whites). The other major area of confusion is in these authors' presupposition that tongue thrust is almost exclusively associated with open bite malocclusion. Using the figures of Fletcher, Casteel, and Bradley (1961) and those of Hanson and Cohn (1973) where tongue thrust decreases in incidence with age, they proposed that "even if these figures are discounted as being incorrectly high, it is apparent that a clinically evident tongue thrust does not necessarily coincide with an open bite malocclusion and, in fact, most often does not". Quite correctly they point out that tongue thrusting is more prevalent than the open bite malocclusion "they are said to cause" and that the association of the two "does not automatically reveal cause and effect". However, the previous discussion has shown that tongue thrusting can be associated with many more aspects of malocclusion besides open bite.

Proffit and Mason then discussed incisor protrusion and tongue thrust. According to them the data at that time did not support the concept that tongue thrusting and incisor protrusion were related. "The shape of the dental arches and the position of teeth within the dental arches do not seem to be strongly influenced by the horizontally directed pressures of the tongue and lips during functional activity such as swallowing and speaking." Referring to studies carried out on Australian Aboriginals and North American whites, they proposed that there was "no reason to believe that incisor protrusion or arch width is related to tongue pressure during swallowing".
Referring then to resting pressures, these authors proposed that a stronger relationship with dental arch form can be seen. Referring to previous unpublished work by Proffit, they claimed that the resting posture of the tongue and lips "is certainly more important in arch width and incisor protrusion than pressures during swallowing, speaking, or eating".

Referring to the vertical or tooth eruption point of view, they described the situation as being "somewhat different". While conceding that the factors that control eruption remain essentially unknown, they suggested that it was possible that light forces produced by an anteriorly positioned tongue tip, can impede eruption of incisors. An open bite would result if, at the same time, there was no impediment to posterior eruption. Citing the work of Wallen (1974), who compared patients with anterior open bite malocclusion to those with normal dentitions, they describe his findings as being "opposite of what the 'swallowing equilibrium' theory would have predicted", since Wallen found that vertically directed forces were less in the open bite group. They concluded that it seemed likely "that the prominent tongue during swallowing in patients with open bites does not produce the altered vertical position of the incisors". Although they do not mention whether Wallen's "vertically directed forces" were taken during swallowing or at rest position, they then went on to suggest that "resting tongue posture may be more important than swallow activity in open bite also". They further suggested that for tongue thrust therapy, "changing of the resting position is more important when tongue therapy is needed for treatment of malocclusion".

Those for tongue thrust being a causal factor:

Although these aspects of cause and effect will be discussed in a later section, a brief account is included at this point to add balance to the discussion of tongue function on malocclusion as a whole.
Hanson and Cohn (1973) claimed that many of the conclusions attributing changes in occlusion to function of the tongue and circumoral musculature were based on clinical judgements or on research revealing associations between form and function with no tight control over variables. The same, they said, was true for conclusions regarding form or structure governing lingual rest position and function in swallowing and speech (dealt with later). Their approach, therefore, was not to consider the variables in a cause-and-effect relationship but, rather, "to view the concurrent presence of tongue thrust and dentofacial abnormalities as coexisting and somehow associated with one another".

Following research carried out by these authors, in which 18 variables were identified and studied in relation to tongue thrust and malocclusion on 178 subjects, they suggested that cause-and-effect relationships could not be deduced from these findings. However, they believed that until definite conclusions could be reached concerning causes of tongue thrust and causes of malocclusions, it was useful to "continue exploring the possibility that both form and function contribute to the persistence of tongue thrust as well as to the development of malocclusions". They claimed that their research results, supported by other research mentioned, did not justify the attitude adopted by some authors that it was not important to view function as well as form in relation to malocclusion.

In conclusion, Hanson and Cohn claimed that their results "added to those found in the literature" lead them to consider the possibility that structure and function act reciprocally upon one another. Many of their findings suggested that any crowding of the tongue, whether from a "narrow maxillary arch, enlarged tonsils, or the presence of an intruding thumb" might well "promote a tongue-thrust habit". Conversely, they added, that after
reviewing research (Weinstein, 1967) concerning the lingual pressures required
to move teeth and comparing that information with measurements of tongue
pressure during tongue thrust, they maintained that it was "difficult to avoid
the conclusion that the tongue does have the strength and the persistence
required to bring about malocclusion."

Dworkin and Culatta, as late as 1980, maintained that the relationships
between tongue strength, tongue thrusting, and dental occlusion
"remained unanswered". Citing the work of Winders (1956, 1958, 1968), Kydd
(1957, 1962, 1963), Scott (1961), and Barrett and Hanson (1974), they pointed
out that when tongue forces are exerted against the teeth, they may adversely
influence dental arch form. Furthermore, they also cited the work of Strang
and Thompson (1958), Weinstein, Haack, Morris, Snyder, and Attaway (1963),
Brader (1972), Proffit (1972), and Mason and Proffit (1974) pointing out that it
may not be the intermittent and short duration forces that are more
influential on occlusion but rather the continuous resting forces of the tongue.

In either case, both these aspects of tongue function, intermittent
forces against the teeth or continuous resting forces, are identifying
characteristics of tongue thrust.

Perhaps more definite evidence was presented by Oversake (1970) who
reported a study on 48 children with "open bites and overjets". These children
displayed malocclusion and associated tongue thrust behaviour. After under-
going therapy for their tongue-thrusting it was found by independent
orthodontists that 39 (81%) showed "positive changes toward more normal
dental configurations", without orthodontic treatment. It was concluded that
there was a functional relationship between tongue thrust and the mal-
occlusions studied, and that tongue thrust had a causal association with the
malocclusions.
It was Barrett (1977) who advocated a closer examination of the tongue/lip relationship in light of the most recent findings at that time. He placed more importance on "oral resting posture" and the attainment of habitual mouth closure. He also suggested that it is "the light, constant pressure of the resting tongue, leaning against dental surfaces, that enhances some malocclusions". This enhancement of the malocclusion by tongue activity was a point taken by Hanson (1976). He claimed that research had "determined that open bite, overjet, and overbite occur concomitantly with tongue thrust to a statistically significant degree". But whether a cause-and-effect relationship existed between malocclusions and "abnormal oral habits" had not been demonstrated conclusively. In conclusion, he adopted the moderate view that there was enough evidence to suggest the possibility that "dental abnormalities and tongue habits may affect each other reciprocally". He also pointed out that insufficient longitudinal research which was well controlled, had been carried out in order to test this hypothesis.

4.1.1.8 Tongue Thrust and Other Associated Disorders of the Dental Structures

If tongue thrust is causally associated with malocclusion then it would seem that it could also be associated causally with other disorders that could be a result of malocclusion. Also, if lingual forces acting on the dental structures can promote change in those structures, then these forces may also produce change in the supporting structures.

Goldberger (1978b) claimed that tongue thrust could be responsible for "shifting teeth, pain, TMJ problems, unerupted teeth, endless expense, unhappiness, gingival recession, bone destruction, and inability to wear dentures". She cited numerous cases involving prosthodontics, periodontics, orofacial pain, jaw joint pain, and oral surgical conditions involving an underlying tongue thrust condition. Going one step further to implicate tongue thrust as being a causal
factor, or the causal factor, she claimed that in all of these cited cases tongue thrust therapy had brought about a cessation of these problems.

Graber (1972) described how, in some cases, bruxism may develop due to the overeruption of the posterior teeth in cases where tongue thrusting increases overjet and open bite. "The postural resting vertical dimension and occlusal vertical dimension become one and the same, with the posterior teeth in contact at all times. This is not a dentally healthy situation."

Stack and Funt (1977) agreed with this assessment and, at great length, described the effect upon the temporomandibular joints of abnormal tongue function. They described cases of patients with severe protrusions, and those with anterior open bites, where resorption of the condylar head resulted from protrusion of the mandible in function. Also described was the adverse effect on the jaw joints resulting from patients with full dentures having to clench their teeth because of constant dislodgement due to an unrecognised tongue thrust.

Returning to periodontal conditions and tongue thrust, it was claimed by Ray and Santos (1954) that "intraoral soft tissue habits" of tongue thrusting affected "the teeth, their alignment, and the periodontal structures".

Graber (1972) also noted the effect on the periodontal tissues of an open bite malocclusion, which he attributed to tongue thrust. He described the supporting tissue pathology (Fig.130a) as having a poor prognosis. Burch (1980) described two swallowing patterns - the "retained" transitional swallowing pattern, and the "adult-acquired swallowing pattern" that develops subsequent to migration of teeth, or tooth loss in an attempt to seal off the oral cavity, thereby enhancing the swallow. Either of these swallowing
Fig. 130a  Adult open bite problem with history of finger sucking and tongue thrust habits. The prognosis of the health of the investing tissues in these open bite cases is poor.  (Graber, 1972)
patterns, he contended, "may result in trauma to the periodontium or mal-
alignment of teeth due to persistent forces applied by tongue, lips, and/or
cheeks".
4.1.2 Deviant Dento-Skeletal Relationships Associated with Tongue Thrust

Moving on to view the influence, if any, of tongue thrust at a deeper level, its relationship not only to dentoalveolar structures but also to underlying skeletal relationships needs examination. For example, if the severe complete bimaxillary protrusion seen in Figs. (87, 123) is produced by "severe abnormal swallowing habit forces" (Straub, 1961), then are these forces influential enough to affect the underlying basal bone? Viewed from a different perspective, will the abnormal function of the tongue influence the growth and development of the underlying skeletal structures?

Can tongue thrust, then, influence the skeletal structures or is tongue thrust an adaptive response, a secondary factor determined by the patient's structural form? As we come closer to the arguments surrounding the causal nature of tongue thrust, are there definite associations between tongue thrust and skeletal deviance, and what is the nature of these associations?

In relating the association between tongue function and skeletal abnormality, Hovell (1955) drew attention to the role of lip incompetence. The causes of lip incompetence, he said, were: short lips; a high Frankfort-mandibular plane angle increasing above normal the distance between anterior nasal spine and gnathion; a post-normal skeletal pattern, the lower lip being placed too far distally relative to the upper; or "any combination or permutation of all three". He claimed that the more severe the lip incompetence, the less effect they have in preventing proclination of the upper incisors by the tongue. A Class II, Division 1 incisor relationship results with proclined upper and retroclined lower incisors. The tendency for this to happen is increased by a post-normal skeletal pattern, as the lower lip is, as a result of this pattern, already related posteriorly to the erupting upper incisors and is more likely to fall behind them.
Hovell pointed out though, that it is possible to get a Class II, Division 1 malocclusion in the absence of an atypical swallowing action. "Severe skeletal postnormality causes the lower lip to lie behind the upper incisors, which are guided by it into a proclined position, exaggerating the overjet already present as a result of the apical base abnormality."

More directly, Straub (1961) attributed the changes in skeletal form during growth to the activity of the tongue. Changes of increased steepness in the mandibular plane angle occurred during growth, he said, "as a result of pressure of the tongue between the teeth during abnormal swallowing over a period of years", the greatest changes taking place in open bite and bimaxillary protrusion cases. He described the mandible as appearing to be "bent" by the position of the tongue between the teeth, either affecting the mandible at gonion, displacing the head of the condyle, or affecting the length of the ramus or rami. Straub also noted the effects, as he saw it, of the tongue in the etiology of Class III patterns, by noting the association between steep mandibular plane angles and Class III cases, assuming that the abnormal tongue behaviour causing the steep mandibular plane was then associated with the Class III malocclusion.

With similar directness, Penzer (1970) stated that an abnormal swallowing pattern can inhibit growth and development of the orofacial complex.

Conversely, Tulley (1964a) believed that the basic inherent size, shape, and relationship of the skeletal structures must be a dominant factor establishing the occlusion of the teeth. He also believed that the lips, cheeks, and tongue are also part of the inherent pattern, acting "as a rubber-like mould influencing the position of the dento-alveolar structures, developing on the jaw
bases". Where the hard and soft tissues do not foster good occlusion of the teeth, he suggested, adverse functions of the lips and tongue may be "added complicating factors", adding that treatment for such patients is likely to be "extremely difficult". The poor prognosis is due to the morphological factors not allowing a better incisor relationship to be established. These skeletal factors are: a discrepancy in jaw relationship (Skeletal II or Skeletal III) with a high maxillary-mandibular plane angle, and a "flaccid, somewhat coarse or heavy" middle third or lower half of the face.

Furthermore, Tulley (1964b) claimed that tongue-thrusting was found in cases having a "dominant morphological defect". Again he said that there was a high angle between maxillary and mandibular planes, and because of this, a ratio between the posterior and anterior face heights of more than 1:2.2, in those subjects with open bite and tongue-thrusting that he studied. He described this facial pattern as one "which gives poor prognosis for the achievement of a good anterior incisor relationship when taken in relation to the soft tissue factors" (Figs. 131, 132). He noted in particular that whatever the cause of tongue thrust, "where there is an excellent facial form, a good occlusion will develop".

Ballard (1953) also discussed soft tissue morphology related to orthodontics. He suggested that with a skeletal pattern and a soft tissue behaviour which would produce a normal incisor relationship without the superimposition of an abnormal swallow, the incisor abnormality tends towards open bite without any increase in overjet. Conversely, if there is a Skeletal II pattern which predisposes to an increased overjet, or if there is an incompetent lip action, which again predisposes to an increase of overjet, then the abnormal swallow will produce a greater overjet and a lesser degree of open bite or reduced overbite. The findings, however, are very variable because the
Fig. 131. Tongue thrust case with excellent occlusion and facial pattern. (Tulley, 1964b)

Fig. 132. Tongue thrust case with poor facial pattern. (Tulley, 1964b)
abnormal swallow is superimposed on variations in the resting position of tongue and lips.

Ballard was also content to believe that tongue thrust was not closely associated with skeletal deformities, "it has not been established whether there is a higher incidence of abnormal swallow associated with certain skeletal deformities." Using a rather flimsy argument that "because we see the abnormal swallowing action associated with a normal skeletal pattern and with Class III skeletal patterns", he concluded that it tended to "exaggerate the deformities which are usually associated with such skeletal abnormalities".

In a later section he also described how the lateral position of the buccal segments and their relationship are also the result of soft tissue balance. Citing the work of Rix he described the abnormal behaviour or posture of the tongue as being an etiological factor in abnormalities in a lateral direction. Quoting two examples, that of a constricted maxillary arch and that of a very broad maxillary arch together with a narrow mandibular arch, he found that in the first case the tongue was usually in a "low resting position". He added that the low tongue position is "almost invariably seen in association with a high Frankfort-mandibular plane angle." In the second case, the tongue was found in a "high resting position".

Skeletally, Cleall (1965) found that there were differences in morphological deviation in tongue thrusters: (1) the chin point was found to be more posterior in the tongue thrusters studied, and (2) there was a greater distance from the palatal plane to the tip of the lower incisor which reflected the high incidence of anterior open bite in the tongue thrust sample. He also found that the oropharyngeal structures of subjects in the tongue thrust group studied performed the act of deglutition using movement patterns which conformed to the limits set by the dentoskeletal arrangement. These results
seem to suggest that the morphology surrounding the posterior region of the tongue is more likely to affect the function of the tongue while the function of the anterior region of the tongue is more likely to affect the dentoskeletal structures in that region. Is there then a progression of events, with the oropharyngeal structures determining the tongue function, thereby influencing the dentoskeletal structures, resulting in anterior open bite malocclusion?

Speidel, Isaacson, and Worms (1972) discussed the role of tongue function in anterior dental open bite. According to them, abnormal form will elicit abnormal function "which may manifest itself as a compensatory function of the tongue and lips". Extreme activity of the tongue and mentalis muscle to effect the necessary circumoral seal during swallowing is required in a case where there is a backward-rotating growth pattern, a normal overbite of zero, and lips barely adequate to cover the teeth comfortably. The open bite tendency is likely to be enhanced by abnormal muscle activity, due to the requirements of the patient's morphology, rather than caused by it. "When an extrinsic influence is superimposed upon a natural tendency, the natural tendency will be enhanced." These authors claimed that abnormal tongue activity is rarely found in patients with a forward rotating mandibular growth pattern. Whereas, in patients with a backward rotating mandibular growth pattern, they claimed that tongue problems were commonly seen.

Recognition of the patient's particular skeletal pattern is "of paramount importance" according to these authors. They asserted that extreme variations in skeletal pattern "are undoubtedly genetically caused and are difficult to prevent totally". Of tongue thrusting they concluded that "in the rare case of an open bite persisting after 10 to 12 years, and when such open bites are not present on backward-rotating skeletal patterns, one may consider the primary etiological factor to be extrinsic, possibly abnormal tongue activity".
In a commentary by King (1983) on these authors' work, he interprets their regard for tongue activity to be "at best a minor, opportunistic influence in the etiology of anterior openbite". King regards their assertion, that only genetic factors are responsible for extreme variation in facial growth, as being unsupported. Further to this study King criticises "persistent and erroneous assumptions regarding occlusal variation" and points to population studies which have indicated that environmental factors are a more "pervasive and important influence on phenotypic determination than previously suspected".

Subtelny (1970) was another who suggested that abnormal tongue posture and activity may be associated with undesirable skeletal relationships such as steep mandibular planes coupled with retrognathic facial patterns. In a discussion regarding "inadequate adaptation" of the tongue to its surrounding structures, he said that in these instances, in addition to a reduction in horizontal oral cavity space, there may not be adequate vertical space, especially in the posterior regions, to properly contain the tongue mass. In citing a study by Fowler (1969) which compared the palato-mandibular plane angles of varying malocclusions, he discussed the impact of the space in the oropharyngeal region on the containment of the tongue mass (Fig.133). The results showed that the severity in deviation from the norm was more pronounced in poor skeletal patterns than in those malocclusions that seemed basically dental abnormalities. "Those judged to be true skeletal problems, such as skeletal open bites and Class II malocclusions with skeletal mal-relationships, were clearly more extreme in deviation." The apparent lack of posterior vertical height meant that the tongue "may be forced to occupy an excessive proportion of the oral cavity within that specific skeletal environment". Tongue protrusive activity might then be more evident in these cases. The frequency of this occurrence in Class II malocclusions, noted previously, might be related to this activity, according to Subtelny. Many of these
Means and Standard Deviations For The Angular Relationship of The Mandibular Plane to The Palatal Plane

<table>
<thead>
<tr>
<th>Occlusion</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Occlusions</td>
<td>24</td>
<td>21.35</td>
<td>5.31</td>
</tr>
<tr>
<td>Class I Crowding</td>
<td>30</td>
<td>26.86</td>
<td>4.77</td>
</tr>
<tr>
<td>Class II (Dental)</td>
<td>26</td>
<td>24.84</td>
<td>4.99</td>
</tr>
<tr>
<td>Muscular Open Bite</td>
<td>10</td>
<td>26.90</td>
<td>5.65</td>
</tr>
<tr>
<td>Class II Skeletal</td>
<td>29</td>
<td>30.20</td>
<td>2.17</td>
</tr>
<tr>
<td>Open Bite Skeletal</td>
<td>28</td>
<td>32.03</td>
<td>6.24</td>
</tr>
</tbody>
</table>

Fig. 133  Table: Angular relationships for mandibular to palatal planes with differing malocclusions. (Subtelny, 1970)

Fig. 134  Poor skeletal relations, large tongue, and lack of posterior vertical height (post-orthodontic treatment). "The tongue seems to be a victim of the oropharyngeal environment". (Subtelny, 1970)
subjects, he said, may have underlying skeletal malrelationships which may contribute to this pattern of function. "Thus, in actuality, the tongue may still be adapting to that specific and unfavourable skeletal environment." Using an example (Fig. 134) he said that in situations like this, "the tongue may continue to be the victim of an unfavourable environment".

Open bite was discussed by Gershater (1972) who studied children in two institutions, the first having intellectually disabled and emotionally disturbed children, the second catering mainly for those with emotional problems ranging from behaviour disorders to psychoses. He found that these children had an unusually high incidence of open bite malocclusion.

Subjects from the first institution showed a 32.3% incidence of "open bite deformity" with 6.1% for "extreme skeletal deformity." The second institution had figures of 6.7% and 1.1% respectively. Associated with these open bite deformities he found "large uncontrolled" tongues, poor neuro-muscular patterns, and psychological factors. The data supplied for the first institution (Fig. 135) show a number of interesting findings. Notable here is that out of the 21 subjects with open bite deformity, over 70% had "abnormal" skeletal patterns, 95% had "abnormal" tongue posture, 66.6% had hyperactive tongue activity, and over 70% had a "large" tongue size. Gershater offered the following reason for the higher incidence of open bite at the first institution (32.3% compared to 6.7%) - that many of these children "lack the necessary muscular control for proper function of the jaw, tongue, mouth and the swallowing pattern". The open bites were in his opinion a "natural result". Especially significant was the high incidence (61.1%) of "extreme skeletal deformity" in this group.

Gershater went on to say that a deviation in the pattern of swallowing
1. Sex: Male — 16, Female — 8, Average Age — 12.6, Average I.Q. — 67.3
2. Angle’s Classification: Class I — 11, Class II: Tendency to Class III — 2, Class II Div. I — 8, Mixed Dentition — 5, Permanent Dentition — 16
4. Degree of Deformity: Incisal Tip to Tip — 4, Slight — 9, Medium — 4, Severe — 4
5. Tongue Posture: Normal — 1, Abnormal — 20
6. Tongue Activity: Normal — 6, Hypoactive — 1, Hyperactive — 14
7. Tongue Size: — Average — 6, Large — 15
8. Swallowing Pattern: Normal — 1, Abnormal — 20
9. Skeletal Pattern: Normal — 6, Abnormal — 15
10. Palate Height: Average — 2, Medium High — 5, High — 14
11. Size and Shape of Arches: Maxillary — Average — 4, Constricted — 16, Large — 1, Mandibular — Average — 1, Constricted — 2, Large — 10, Proportionate — 7, Disproportionate — 14, Cross Bite — 6
12. Mandible: Ramus-Average — 12, Short — 9, Cross Bite — 6, Body Deformed — 6
13. Chin: Normal — 15, Macroglossic — 5, Macroglossic — 1
15. Tonsils: Small — 4, Average — 7, Large — 2, Removed — 8
17. Habits: Finger or Thumb-Sucking — 10, Lower Lip — 8, Mouth Breathing — 10
18. Muscular Coordination: Poor — 10, Fair — 5, Good — 6
19. Psychological Evaluation: None — 4, Light — 2, Medium — 5, Severe — 12
22. Allergies: — 6
23. Prognosis: Good — Fair — 1, Poor — 20

Fig. 135 Data for the first institution. (Gershater, 1972)
can influence the growth patterns of both the maxilla and mandible. He stressed the influence of factors such as tongue thrust on the skeletal structures. "Congenital inherited patterns have a decided influence on the growth and development of the orofacial structures, but adverse environmental factors can markedly exaggerate the open bite deformity."

Thurow (1975) was perhaps the main force in drawing attention to the importance of the pharyngeal airway and related skeletal structures. "A limited airway will be commonly found in cases with small steep mandibles, and disproportionate vertical development." One possible secondary effect of maintaining a patent airway, he said, is open bite. He mentioned that protruding the tongue between the teeth can be effective in increasing the size of the airway. This is not a "simple tongue thrust habit" he points out, since it tends to be a result of, and a contributing factor in, skeletal disharmony related to maintaining an adequate airway. In comparison to Straub's (1961) description of the mandible appearing to be bent by the position of the tongue, Thurow described this process in a similar way.

In a later discussion (Thurow, 1977), he described how nasal airway obstruction could influence mandibular loading brought about by changes in tongue and hyoid relationships. Similarly obstruction of the lower pharyngeal airway can have profound effects on mandibular growth. It can also cause and aggravate many secondary problems. Describing the effect on the tongue anteriorly, he pointed out that the tongue may have to rest between the teeth or thrust between them during swallowing, as an accommodation to anatomic disharmony.

In another study on open bite malocclusions, Subtelny and Sakuda (1964) thought that "there was not sufficient evidence to permit the
categorical statement that the tongue was the causative factor" in cases where "aberrant skeletal development" was found. They added, however, that "it could not be ruled out completely as a possible contributing or even causative factor". They concluded that "for one reason or another, there can be an aberrant development of the skeletal structures of the face, causing a distortion in the occlusion - a persistent open bite". Thus abnormal function was not ruled out as a causative factor.

They also noted that cases must be viewed individually, and tongue size and degree of physiological activity must be considered. Citing an example of a patient with a large tongue and "a minimal neurologic deficit" which prevented full control of tongue activity (Figs.136,137), they showed the impact of a "consistently protruded tongue superimposed on an abnormal skeletal base". The combination of these factors, they suggested, led to the severe open bite malocclusion shown.

They proposed that the association between tongue function and skeletal open bites must be viewed closely. The adaptive function of the tongue must be differentiated from the tongue as a causative factor. The authors, however, could not offer such a method of differentiation. The causes of an open bite they listed as: a morphologic abnormality resulting from a disturbance in skeletal development, an expression of muscle growth and muscle function, or a malplacement of the anterior teeth. The skeletal and muscle relationships must be considered as well as the dental relationships. The inference was, then, that abnormal tongue function can play a causative role in skeletal open bites. "If treatment is attempted considering one factor alone - the opening between the anterior teeth - the results may be disturbing and disastrous."
Fig. 136  Severe anterior open bite, large and excessively active tongue, with minimal neurological deficit. (Subtelny and Sakuda, 1964)

Fig. 137  Tracing of case in Fig. 136. Abnormal skeletal base, size and posture of tongue. (Subtelny and Subtelny, 1964)
On maxillary skeletal development, Hanson and Cohen (1973) reported the findings of a longitudinal study of 178 children and found that the retention of a tongue thrusting pattern through the period of the mixed dentition was found to be positively correlated (p < 0.05) with the following skeletal factors:

- A narrower palate at the premolar and canine levels;
- Greater palatal length; and
- Greater palatal height at canine and premolar levels.

Another finding was related to the extent of the movement of the hyoid bone during swallowing which was recorded. There was a positive correlation (p < 0.01) between this criterion and the anterior and posterior available vertical space at the maxillary level as shown on radiographs of the subjects. In a review of this study, Barrett and Hanson (1978) described this relationship as a logical one and that it "demonstrates the involvement of the extrinsic lingual musculature in raising the tongue to the roof of the mouth when the arch is high". These authors, however, were quick to point out that many other correlations from this study were found to be inconsistent and therefore whether these findings were meaningful overall is questionable.

Returning to open bite cases, Nahoum (1977), in discussing treatment, presented six case studies illustrating a skeletal component of the open bite. In all these cases he used his index of upper anterior face height to lower anterior face height (UAFH/LAFH) as a guide to determining the severity of the open bite. He had found that for subjects with a normal dentition and a good face, the ratio is 0.810, and for patients with open bite malocclusion it is 0.686. Subjects with deep bites, he found, had ratios above 0.900. The ratio then, is a guide indicating the severity of the vertical dysplasia and hence a guide in predicting the results of treatment. "Patients with a dental open bite
and a UAFH/LAFH ratio below 0.650 are considered poor risks for conventional orthodontic treatment," he said. "A surgical procedure should be considered for these patients."

The six patients he presented all exhibited anterior open bite malocclusions with facial dysplasia. In each case, except for one, the UAFH/LAFH ratio was close to the 0.650 ratio, being "poor risks for conventional orthodontic treatment". However, all these patients underwent orthodontic treatment which was largely successful except for two cases where the ratios were 0.613 and 0.561. Both of these were subsequently regarded as surgical/orthodontic cases.

The most interesting point insofar as this discussion is concerned, is that in each case, tongue thrusting was a concomitant condition. Moreover, as part of Nahoum's therapy for each of these six cases, corrective treatment for the tongue thrust was instituted immediately. This therapy was in the form of myofunctional therapy (described in a later section) to establish a normal swallowing pattern. Obviously then, Nahoum was convinced that there was a definite association between tongue thrust and skeletal vertical dysplasia. He had found that "most open bites" were deficient in: (1) growth of the upper face, and (2) growth of the posterior face. Although, "some varieties have adequate posterior face height". However, a compensatory increase in lower anterior face height occurs in both types. By the way he approached the treatment for his patients then, the aspect of tongue thrust as being a causal factor rather than an adaptive factor in these dento-skeletal disorders, was exemplified.

Finally, a remarkable example of tongue function influencing skeletal tissues was presented by Atkinson (1966). In discussing the tendency of growing
bones to follow the line of least resistance, he cited an example of how "even good, well-calcified bones may be influenced" (Figs.138-140). The case shown was of a complete palatal cleft case. According to this author, ordinarily the sides of the dental arches and the face would have been expected to collapse or at least become excessively narrow. The tongue would rest on the floor of the mouth, producing a Class III malocclusion and an underdeveloped, sunken-in maxillary arch, plus a protruding chin. Instead, a well-developed maxillary arch, a "wonderful occlusion, jaw relation, and development", and well-developed facial bones are seen.

According to Atkinson this result was achieved by "muscle and bone working together" with bone following the line of least resistance, with no conflicting pressures. In swallowing, he said that the tongue had to be forcibly held in the roof of the mouth at all times, allowing the bolus to follow the usual route to the oesophagus. The tongue then had to be kept there by muscular activity, as the cleft "precluded any possibility of suction or atmospheric pressure existing". The influence of the tongue therefore was to re-establish a harmonious balance between muscle and dentoskeletal structures by its own abnormal function.

Clearly then, there is much diversity of opinion concerning the nature of the association between tongue thrust, malocclusion, and deviant dentoskeletal relationships. Between the two extreme points of view of Tulley and Straub it appears that a more realistic attitude to the association would be to accept that neither malocclusion and adverse skeletal form, nor abnormal tongue behaviour by themselves, could be shown to be sole causal factors of malocclusion. It would seem then, that tongue thrust has both a causative as well as an adaptive association in such cases.
Fig. 138  Complete palatal cleft case - normal arch form. (Atkinson, 1966)

Fig. 139  Complete palatal cleft case - normal dentoalveolar relations. (Atkinson, 1966)
Fig. 140  Complete palatal cleft case - normal posterior occlusion. (Atkinson, 1966)
4.2 Cause-Effect Relationships

The realm of cause-and-effect has been entered. Many aspects regarding causation and tongue thrust have been discussed previously; can any more light be shed on these? A fuller examination of causal influences needs to be undertaken, for the influence of tongue thrust has been linked, as shown, to many broad areas of discussion and particularly to conflicting opinion regarding form and function. The three major subjects, it seems, of controversial discussion and still unresolved conflict of opinion related to tongue thrust are: Equilibrium Theory, Open Bite Malocclusion, and Naso-Respiratory Function. These have been touched on in previous sections. This section will deal with these matters more fully.

The aim here is not to dwell on each area in unnecessary detail, as each topic could be turned into a dissertation of its own, but rather to take the salient features of each and relate them back to this discussion on tongue thrust. To become caught up in the polemic of each subject would be counter-productive to this discussion.

4.2.1 Equilibrium Theory of Tooth Position

4.2.1.1 The Theory

As Moyers (1973) pointed out, it has been believed that each individual tooth is positioned between sets of contracting muscles - those of the tongue on the one side and those of the lips and cheeks on the other. As long as the total pressure acting against the teeth is balanced throughout time, the position of the teeth is stabilised. Also, that whenever there is a radical change, throughout time, in the muscular environment around the tooth, the tooth will be moved through the bone until balance is again achieved.
How well founded is this belief?

The work of Weinstein, Haack, Morris, Snyder, and Attaway (1963) supported this contention. Conversely, the work of Lear and Moorrees (1969) could not find support for this assumption that dental arch form reflected the influences of the surrounding buccolinguial musculature.

It must be pointed out, however, that one of the main problems has been the inability to measure all the forces acting on the teeth simultaneously. Most normal forces are within ranges tolerated by the surrounding bone or counteracted by other forces acting against the teeth. Gross upsets, such as tongue thrusting, digital sucking, or orthodontic appliances, can occur in such a stabilising system, "bringing movement of teeth and deformation of the alveolar process, until balance again is achieved in a new relationship of parts". Moyers drew attention to the complexity of the variables involved and the relationship between force and bony response. This bony response "although assumed to be linear in most experiments, is not really known". He suggested that this complicated matter will not be understood until: "(1) the level and nature of force thresholds and gradients necessary for bony responses are known, (2) the factors of direction, deviation, and rate of force application are perceived, and (3) systems are available for monitoring all of the many forces involved simply, reliably, and continually". Let us now look at the concept of dental equilibrium more fully.

**Historical Background**

Tulley (1969) has given an excellent account of the lead-up to the formulation of this theory, mentioning numerous authors of the mid-19th century. The concept of labiobuccal muscular environment can be traced to Tomes (1873) who suggested that "the agency of the lips and tongue is that which determines the position of the teeth".
This view has since been endorsed by many orthodontists. Angle (1907) crystallised the concept in the seventh edition of his classic text "Treatment of the Malocclusion of the Teeth". He wrote of the "harmony of balance" between intra-oral and extra-oral muscle pressures. Other authors have contributed to this belief. Mentioned by Tulley were Bennett (1914), Friel (1926), Brash (1929), and Rogers (1918a, 1918b, 1939). By the late 40's to late 50's the topic had received a great amount of attention from British and American authors. Rogers (1946, 1953), Rix (1946, 1948, 1953), Brodie (1950, 1952, 1953, 1954), Ballard (1951, 1953, 1957), Gwynne-Evans (1951, 1954, 1956), Straub (1951), Klein (1952), Hovell (1955, 1956), and Graber (1958) were among the most prominent writers.

Interestingly, Klein (1952), in accordance with his observations on orthopedic influences on bone and the application of pressure to bone (Figs. 141, 142), attempted to explain malocclusion in terms of "abnormal pressure habits". These types of forces he believed were primarily responsible for the changes in balance of the dentition.

Graber (1958) described the balancing of extra-oral and intra-oral muscular forces (Fig. 144), and depicted the passive restraining influence of the buccal and perioral musculature on the anterior displacement of the teeth, as being like a piece of rubber dam wrapped around the skull (Fig. 143). Weinstein's diagram of the "buccinator mechanism" was also shown to illustrate the point. Later, Graber (1973) also asserted that there was an "obvious role of muscle and its influence on the tooth and bone systems", despite the fact that not all is known about muscular balance and imbalance. He wrote of the imbalance caused by abnormal activity or posture of the tongue, particularly in tongue thrust. However, he pointed out that imbalance is countered by the re-establishment of balance or homeostasis, "even with a malocclusion and perverted and compensatory perioral muscle function, a state of balance of all
Fig. 141  Application of pressure to bone - Flathead Indian (intentional, planned pressure).  (Klein, 1952)

Fig. 142  Orthopedic effects on bone - bowlegged cowboys from continuous horse riding (unintentional pressure).  (Klein, 1952)
Fig. 143  Restraining effect of oral and facial muscles.  (Graber, 1958)

Fig. 144  Drawings depicting the balance of postural and functional forces inside and outside the dental arches.  (Graber, 1958)
factors, muscular and others, is reached. It is important ... to realise that a malocclusion represents nature's attempt to establish a balance of all morphogenetic, functional, and environmental components. A malocclusion is in dynamic balance at that particular time."

Some authors (Rogers, 1961; Straub, 1951, 1960, 1961, 1962) made sweeping generalisations regarding the influence of the tongue on the equilibrium of the teeth. They claimed that "abnormal tongue movements" during the act of swallowing will produce abnormal tooth positions. Is this the case? Can the tongue be so influential as to cause adverse positioning of teeth during the relatively short periods of time per day that it contacts the teeth during swallowing? At that stage no real attempts had been made to see if this was true. According to Abrams (1963) the data available up until the early 60's were "misleading", and the instrumentation "inadequate".

Therefore, the assumption that swallowing pressures caused the abnormal tooth positions, would seem to be far from "obvious". The concept that resting tongue posture or resting perioral posture could be responsible did not seem likely at that stage.

Scott (1961) was one author to begin casting doubt on the "dogma" attached to the then current line of thinking. He pointed out that there was no proof of this hypothetical assessment of arch function. He suggested that the form of the dental arches is the consequence of a number of developmental and functional influences including genetic factors regulating skeletal form, the ratio between tooth size and bone size, the developmental position and paths of eruption of the individual teeth, and the forces exerted by the oral and masticating musculature. He urged that an assessment of balance of forces must include all these factors.
4.2.1.2 Testing of the Theory

A number of researchers then attempted to measure these 'balancing forces', Feldstein (1950) being the first using "pressure capsules" attached to the teeth. What they found had not been anticipated. Winders (1956) found that during function the force exerted by the tongue was as much as four times as great as the balancing buccal and labial musculature.

Correspondingly, Kydd (1957) found that maximal lingual pressures were approximately twice the magnitude of the labial pressures. He was one of the first to cast doubt on the concept of lingual forces being balanced by labial forces. However, he pointed out that there must be other forces operating, "to equalize this apparent imbalance of musculature". These forces, or rather, conditions aiding resistance, he suggested, included the inclination of the teeth, the density and thickness of alveolar bone, the length of the tooth roots, the length of the clinically apparent crowns, and the forces of occlusion. No mention was made at this stage of resting posture forces, but he did suggest that duration of forces was worthy of further investigation, "the lips may exert a lower pressure for a longer duration than the tongue".

In another study Winders (1958) found again that the tongue exerted a much greater force on the dentition than did the perioral musculature. He also found that there was no statistically significant difference between the pressures incurred during swallowing in a group of subjects with normal occlusion compared to a Class II, Division 1 malocclusion group. However, this could have simply meant that the forces on the teeth were measured after the teeth had achieved an equilibrium position.

Kydd, Akamine, Mendel, and Kraus (1963) found that the basic difference between anterior open bite subjects (tongue thrust group) and subjects without an anterior open bite, was in the duration of lip and tongue
pressures applied to the anterior teeth. The tongue thrusters applied both tongue and lip pressure against the anterior teeth for a longer duration than did the subjects without an anterior open bite.

With these sorts of findings now coming through, it was obvious that a reappraisal of the original concept of muscle balance was required.

Weinstein, Haack, Morris, Snyder, and Attaway (1963) astutely pointed out that each tooth is in equilibrium with its surroundings at any instant, whether or not it is in an equilibrium position. Thus the term 'equilibrium position' should not be confused with the term 'equilibrium'. They stressed that in addition to considering those factors which determine an equilibrium position, it is also necessary to consider the stability of such positions and the conditions under which equilibrium positions may be stable or unstable. Equilibrium positions may not necessarily be stable positions. Fundamentally, they said, the stable position is differentiated from the unstable one by the level of the potential energy stored in the surroundings of the tooth. Since relatively little energy can be stored in the bony structure due to its great stiffness, most of the storage will take place in the surrounding soft tissue, principally in the musculature. They wrote:

"Equilibrium positions will always be positions of maximum or minimum potential energy. Those characterised by maximum potential energy are intrinsically unstable, while those which have minimum potential energy are stable. Furthermore, since there may be several positions for which the potential energy is a minimum, there will like-wise be as many stable positions of the tooth in question. In general, a body subjected to a small displacement from a stable position of equilibrium will return to the stable position upon removal of the displacing force. Correspondingly, a body displaced from an unstable position of equilibrium will not return to a stable equilibrium position."

Importantly, Weinstein et al. made reference to the reactive forces applied through the periodontal ligament. These they described as "an
equilibrating system of forces", acting on the root of the tooth. These reactive forces are supplied by the bone acting through the medium of the periodontal ligament "and in the final analysis are the factors which initiate osteoblastic and osteoclastic action and the concomitant tooth movement".

From their studies they concluded:

(1) Forces exerted upon the crown of the tooth by the surrounding soft tissue may be sufficient to cause tooth movement in the same manner as that produced by orthodontic appliances;

(2) Each element of the dentition may have more than one position of stable equilibrium within the system composed of the natural oral environment; and

(3) Differential forces, even when they are of small magnitude, if applied over a considerable period of time, can cause important changes in tooth position. "These forces are from 1/4 to 1/10 of those generally recommended as minimum forces for orthodontic treatment." They suggested then that differential forces much smaller than those ordinarily used in orthodontic treatment can, with protracted application, produce easily measured displacements. Weinstein (1967) later found that muscle forces of such low values as 1.68gm above the resting force, if acting over a sufficient time, are capable of moving teeth.

Gould and Picton (1964) studied lip and cheek pressures in the incisor, premolar, and molar regions in subjects with established normal occlusions. They found that more force was always present in the first premolar regions than elsewhere. This region corresponded to the modiolus muscles. They also found that the total force acting on the first molars was similar to the total force on the incisors. Their results also implied that individuals tended to
exert more force on one side of the mouth than the other and that, as a group, the force on the right side was frequently the greater.

Bandy and Hunter (1969) found from their studies on tongue volume that neither the size nor the pressure of the tongue appeared to have as great an influence on the size of the dental arch as was thought.

In contrast, Brader (1972) studied the geometry of the dental arches and the effects of opposing muscular forces upon those arches. From his findings, he postulated that the teeth do reside in positions of equilibrium, forced anteriorly and laterally by the tongue musculature, and are counterbalanced precisely along the interface between the teeth and labiobuccal mucosa by the inward tension of the enveloping tissues.

What factors or combination of factors then, control physiological movement of teeth? The indirect evidence coming from clinical studies on the importance of the tongue in maintaining arch form have shown one very convincing side of the case. The work of Eskew (1949), Briggs (1965), Gardner (1960), Walker (1962), Proffit, Gamble, and Christiansen (1968) and Moss (1980) have shown the effects of: complete congenital aglossia (maxillary and mandibular teeth and the alveolar bases severely constricted); partial congenital aglossia (similar findings); lymphangioma of the tongue (anterior dental spacing, with a stable correction after partial resection of the tongue and minor orthodontic treatment); generalised muscular weakness (with normal posture and behaviour of the tongue but with severe anterior open bite); and cancrum oris (with outward displacement of cheek teeth after destruction of buccal tissues).

Conversely, Subtelny and Sakuda (1966) observed the forward
movement of lower incisors in only 44% of patients treated with lip bumpers. This implied that the influence of the tongue was not as great. Conflicting observations have also been reported on the role of the facial muscles. Briggs, again, observed a girl with a congenital cerebrofacial palsy. This patient displayed no lip or cheek activity, yet the incisors were well-aligned.

Efforts to quantify muscular activity then, had failed to substantiate the equilibrium theory. As a consequence, the role of functional forces was de-emphasised - Lear and Moorrees (1969) on intermittent functional activity, and Proffit, Chastain, and Norton (1969) on tongue resting posture.

4.2.1.3 Tongue Posture and Equilibrium Theory

An equilibrium concept for the maintenance of tooth position then, evolved from the observation that very light forces are able to move teeth while the dental arch form is relatively stable under normal circumstances. If forces as low as 1.68gm above the resting level, acting over sufficient time, are capable of moving teeth, then natural forces exerted on the teeth must be in balance or movement of teeth would occur. It was found that the position of dentoalveolar structures can be altered by procedures that potentially would disturb a state of equilibrium of the teeth.

In 1968, Harvold found that altered neuromuscular functions of the tongue could be linked to deviant orofacial morphogenesis. He placed a piece of acrylic in the palatal vault of the rhesus monkey to change physiological relationships and, one year later, the animal manifested an anterior open bite and increased spacing of the teeth. In another group of animals, a two centimetre-long wedge was removed from the midsection of the tongue. After four to six months, deepening of the bite and crowding of mandibular incisors became evident.
However, as Christiansen, Evans, and Sue (1979) point out, investigators have had little success in clarifying the equilibrium concept by determining the specific factors that influence tooth position. Both the resting and the functional forces present in the oral environment have been implicated. Also, the forces of occlusion and dental eruption, morphology of teeth, and inclination of teeth must be considered in a study of dental equilibrium.

As Saadia, White, and Tsamtsouris (1980) point out, the teeth are subjected to different forces for varying amounts of intensity, duration, and frequency, and in different directions (Fig.145). Again, the tongue has been found to be two to three times stronger than the perioral musculature, while the forces of occlusion are much stronger than the forces of eruption. Why then, are not these teeth intruded and tipped buccally? This is "because the labial and tonic forces counterbalance the dynamic forces exerted by the tongue". According to these authors, and using support from Jacobs (1969), "tonic muscles are more responsible for malocclusions than phasic muscles because movement occurs as a result of intensity, duration, and frequency, not intensity alone". Thus:

\[ \text{Movement} = \text{Duration} + \text{Frequency} + \text{Intensity} \]

By tonic and phasic muscles, they refer to phasic muscles as having high-intensity activity sustained for a short period of time, while tonic muscles have low-intensity activity sustained for a longer period of time (Fig.145 a). "In a balanced face, there would be a harmonious relationship between them." Muscles work as a "unit", according to these authors, "and it has been found that a weak tonic muscle will have a compensatory hyperactive phasic muscle; for example, a hypoorbicularis muscle will result in a hypermentalis muscle". Can this be the same with respect to labial/lingual muscular activity?
Fig. 145  Different forces exerted on teeth.
Duration:  length of arrow.
Frequency:  closeness of wave.
Intensity:  width of arrow.  (Saadia et al., 1980)

Fig. 145a  The phasic muscle activity (above) shows a high level of activity for a short period of time, while the tonic muscle activity (below) shows a low-intensity level sustained for a long period time.  (Saadia et al., 1980)
Christiansen et al. (1979) found that (1) the normal relaxed tongue produced a very low force against the lingual surfaces of the mandibular dentition, and (2) the level of lingual force in patients with a dental open bite was found to be similar to that of normal subjects. These findings, therefore, could be explained on the basis that the muscular forces had already reached a satisfactory balance and that no difference in forces could really have been expected.

In an earlier study of tongue function by Swinehart (1950) it was found that if the tongue was encouraged to assume a more normal position in the oral cavity, then a more adequate mandibular arch form and dental alignment could be re-established. He conceded that the basal bone of the mandible "tends to approximate hereditary form and size if given proper function", and although it initiates arch form prior to dental eruption, the teeth "have distinctly different laws of development and growth". He proposed that after the crowns of the teeth migrate away from the basal bone into the oral cavity, the environmental forces there become potent factors in positioning the crowns of the teeth. Citing the work of Eskew and Shepard (1949) on congenital aglossia, he then suggested that proper tongue function on teeth and alveolar bone during tooth formation and eruption "logically appears as a necessary natural force in production of the desired arch form".

Here then, was one more clinical study in conflict with, say, the findings of Subtelny and Sakuda (1966). It would be interesting to find out the resting pressures of the tongue against the teeth in tongue thrusters. Barrett and Hanson (1978) in a critique of the work of Lear and Moorrees (1969) found many deficiencies in their research method. One, was combining of the maxillary with the mandibular data on pressure values, which were
distinctly different. Lingual forces were far greater in the mandibular arch than in the maxillary. The inference of the lingual-to-buccal pressure ratios (maxillary 0.9, mandibular 3.8) is that either the tongue exerts far more pressure on the mandibular arch than the maxillary arch, or that the perioral pressures are far less on the upper arch than on the lower. More studies of this type displaying the raw data were advocated.

Scott (1961) posed the question after reviewing data on suckling behaviour: "If sucking does not normally deform the deciduous arches, why should the 'persistence of the suckling behaviour pattern' deform the permanent arches, unless it has become transformed into a habit involving the abnormal use of muscle activity and the exertion of abnormal pressure on the teeth and alveolar bone?" If the same types of swallowing patterns are seen in the infant and in the tongue thrust swallowing, then why is there not evidence to show that nearly every infant's dentition shows signs of deformity? Perhaps the tongue's behaviour changes due to other influences, e.g. airway maintenance or abnormal growth and development, into a pattern which will adversely affect the developing dentition. Or perhaps there is a higher incidence in "abnormalities of dental relationship" in the deciduous dentition. There seems to be no data, even to date, to support the assumption that tongue thrust swallowing, as a natural occurrence, does not adversely affect the deciduous dentition. Other factors such as pacifier (dummy) sucking, digit sucking, bottle feeding or sucking time, etc. would also have to be taken into account.

Scott pointed out that it is necessary to distinguish between the persistence of suckling patterns of tongue and lip behaviour and the establishment of habits of quite distinct nature, although perhaps arising from the suckling pattern. The inference here in the light of recent research is that
abnormal posture is, again, the major influence, and could arise from the suckling pattern, as in the retention of infantile lingual posture patterns, or develops later, as Hanson and Andrianopoulos (1982) have found.

Returning to the oral balance situation as a whole,Thurow (1977) described the "total force field" surrounding the teeth as a complex web, with many variations in direction, intensity, and duration. He classified the forces according to their source, thus:

A. Intrinsic forces - applied to the root through the surrounding tissues.

B. Extrinsic forces - applied to the crown.

1. Adjoining structures:
   a. Tongue
   b. Buccal musculature (lips and cheeks)

2. Dental function (occlusion) derived from the closing muscles:
   a. Axial (loading)
   b. Eccentric (loading)

3. Extraneous objects (habits):
   a. Thumb, fingers
   b. Holding of foreign objects (musical instruments, smoking materials, pencil)

4. Iatrogenic forces (dental appliances):
   a. Prosthetic
   b. Orthodontic.

Thurow mentions that each of these forces is unique in its own pattern of direction, duration, and intensity. With all these forces acting, presumably in some form of dynamic balance, how can the tongue's influence be singled out and examined?
A number of studies have attempted to identify cause-and-effect relationships between tongue thrust and malocclusion. A study of monkeys designed by Harvold, Vergervik, and Chierci (1973) was such an attempt. Acrylic blocks were placed in the posterior palates of the animals, thus forcing the tongue forward. Open bites and changes in arch width were created during the nine-month period of the experiment.

Another study on cause-and-effect relationships by Negri and Croce (1965) observed the effect of total glossectomies on ten rats. Three months after surgery, the diameters of both jaws in the experimental rats were measured to be significantly smaller than among the controls.

What of the effect of duration of forces? Using data collected by Lear and Moorrees (1969), Barrett and Hanson (1978) calculated the percentage of daily time spent, by the subject who was discussed, in each of the activities studied (Fig.146). They pointed out that for 21 hours in one day the tongue was in a resting position. Applying this finding to the amount and duration of force needed for orthodontic movement of teeth they emphasised the importance of the resting position of the tongue in the determination of tooth position. The resting position of the tongue, they also suggested, "will according to our clinical experience, strongly affect the position and movement of the tongue during speech and during swallowing".

These authors related the pressures found with the time spent; e.g. for liquid swallows: 3.7 to 4.7gm, and 0.3% of subject's daily time, as opposed to much less pressure but longer time for resting tongue pressures. In conclusion, they believed that all the activities mentioned are interrelated and that the resting posture of the tongue is the key determinant of the direction and force of the tongue in the other activities in which it is involved. They then
<table>
<thead>
<tr>
<th>Activity</th>
<th>Minutes</th>
<th>Percent of daily time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech</td>
<td>60</td>
<td>4.1</td>
</tr>
<tr>
<td>Food chewing and swallowing</td>
<td>97</td>
<td>6.7</td>
</tr>
<tr>
<td>Liquid swallows</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>Saliva swallows</td>
<td>12</td>
<td>0.8</td>
</tr>
<tr>
<td>Rest</td>
<td>1283</td>
<td>88.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1456</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Fig. 146 Table: Time spent in activities involving lingual pressures. (Barrett and Hanson, 1978)
recommended replication of this research, comparing children who tongue thrust and who have malocclusions with children who have normal occlusion and normal swallowing patterns. They suggested that lingual pressures exerted by tongue thrusters are not strong, intermittent pressures but rather are light, variable, but very persistent, continuous ones.

In an earlier study on labio/lingual pressures during swallowing, Akamine (1962) had found that the basic difference between "thrusters and non-thrusters" was that the thrusters applied tongue and lip pressure against the anterior teeth for a longer period of time than did the non-thrusters.

Clearly then, further research was needed. A later study by Dworkin and Culatta (1980) attempted to relate tongue strength to tongue thrust and open bite. Beginning by quoting the work of Winders (1956, 1958, 1968), Kydd (1957, 1962, 1963), Scott (1961), Barrett and Hanson (1974), Strang and Thompson (1958), Weinstein et al. (1963), Brader (1972), Proffit (1972), and Mason and Proffit (1974), they described how this relationship remained unanswered. The results of this study showed that children with anterior tongue-thrusting during swallowing did not have significantly stronger protrusive tongue forces than children who did not thrust. However, it should be noted that protrusive forces were studied, not resting pressures. It is likely that with the change in arch form of the open bite subjects, a new equilibrium point for tongue protrusive forces was established, the teeth now being in a new stable equilibrium position.

Hanson and Albridge (1977) reasoned that if it is considered normal for lingual pressures to exceed labial pressures in persons with normal occlusion, it could be expected that greater differences favouring lingual pressure over that of buccal or labial pressure occur in individuals with tongue thrust and malocclusion.
Citing the work of Mendel (1962) to support this hypothesis, they pointed out that this study does suggest that greater differences between lingual pressures and labial/buccal pressures exist between individuals who tongue thrust and those who do not. Again using the studies of Lear and Moorrees (1969) and Weinstein (1967) they suggested that the light, constant pressure of low, forward lingual resting posture and the stronger, intermittent pressures exerted by tongue thrusting during chewing and swallowing of food, and moving and swallowing of saliva, may either tip anterior teeth labially or hinder their eruption. Going further, they suggested, "once the tipping process began or the open bite started to develop, the constancy of the labial/buccal pressure would tend to diminish as it became increasingly difficult for the person to keep his lips at rest. This would further contribute to the increased tongue-to-lip pressure ratio."

The work of Proffit and co-workers (Proffit, 1972, 1973, 1975, 1977, 1978a, 1978b; Proffit et al., 1964, 1965, 1968, 1969, 1970, 1975a, 1975b) has examined the concept of an equilibrium of forces and the influence of intrinsic and extrinsic factors affecting the occlusion. The studies performed have culminated in the belief that while no balance of pressures has ever been observed using various forms of measuring devices (the results consistently show higher lingual forces than perioral forces (Fig.146a)), "there can be no doubt that there is an equilibrium". He (Proffit, 1978a) discussed at length:

(1) Primary factors in equilibrium -
   A. Intrinsic forces: tongue versus lips;
   B. Extrinsic forces: external pressure habits and orthodontic appliances;
   C. Forces from dental occlusion;
   D. Forces from the periodontal membrane: eruption forces; and

(2) Secondary factors in equilibrium -
Fig. 146a  Studies using pressure transducers show that there is an imbalance between tongue and lip pressures, both during swallowing and while they are at rest. Figures for swallowing are typical maximum pressures during the act. Although there is considerable individual variation in pressure magnitudes, the ratios between lingual and labial pressures seen in this example are typical. (Top) Sagittal view; (Bottom) Frontal view. (Proffit, 1978b)
A. Influences on postural relationships in the stomatognathic system; and

B. Secondary factors relating to eruption forces.

In summary, Proffit believed that the major primary factors in the dental equilibrium "appear to be resting pressures of tongue and lips, and forces created within the periodontal membrane, analogous to the forces of eruption". In the vertical plane, he suggested that forces from occlusion "probably also play a role in the vertical position of teeth by affecting eruption". The clinical significance of an altered pattern of swallow, he suggested, "probably lies in its relationship to a different resting posture rather than with the swallowing act itself".

He also related respiratory needs to tongue posture. "Respiratory needs influence head, jaw, and tongue posture and thereby alter the equilibrium." These findings are in accordance with those of Thurow (1975, 1977) and will be looked at more closely in a later section. In the light of these findings, therefore, Proffit found that tongue thrust was "more likely" to be an adaptation than a cause of tooth changes, with a reference also to hereditary considerations. He suggested, using as an example the higher incidence of open-bites among American blacks compared to whites, and the higher incidence of deep bites among whites compared to blacks, that environmental influences on dentofacial development are important "primarily in patients whose inherited facial and dental characteristics make them particularly susceptible".

Barrett (1977) has also come to the conclusion that oral resting posture is of prime importance, "it seems impossible to overemphasize the significance of oral resting posture". He also found it "inconceivable" that the untreated, "thorough-going" tongue thruster would ever achieve normal posture.
"Unable to form a bolus, and thus required to drop the tongue for each swallow, it would be unrealistic to expect the tongue to remain poised in the palatal vault, giving necessary assistance to mandibular elevation and lip closure." It appeared to him that it was the light, constant pressure of the resting tongue, leaning against dental surfaces, that enhances some malocclusions, rather than the intermittent force of tongue thrust. Just as pertinent, to him, was the light, constant pressure of closed lips, focused on the crown of the tooth, "that can assist in correcting some malocclusions".

4.2.1.4 Perioral Influences and Equilibrium Theory

Jacobs, and Brodie (1966a, 1966b, 1967, 1969) have examined the nature of perioral muscular activity anatomically and physiologically. In earlier work it was found that the relationship between mandibular and maxillary contractile muscle forces, and tonic (resting) muscle forces or static tensions could be expressed as a ratio. This ratio was called the Index of Muscular Accommodation (I.M.A.), and for young subjects with normal occlusion was found to be 1.43.

They also found that the muscular modiolar configuration (Fig. 52) was the pivotal point for the converging muscular influence of the oral vestibular forces. "The dynamic state of equilibrium of intraoral and perioral forces involves a constant reciprocal accommodation of function and structure of soft and hard tissues. This process follows a chain of intermediary interactions and feedbacks to manifest itself as a clinical observable entity which can be defined by Angle's classification." They found that the point of fixation of the modiolar pivot and consequent redistribution of forces will be affected by a disharmony between the size, shape, and/or relation of mandibular and maxillary skeletal bases and/or dentition. They found that the I.M.A. for subjects with varying malocclusions changed (Fig. 146b) the highest value being for Class II, Division 1 malocclusion, the lowest for Class I
Index of Muscular Accommodation.

<table>
<thead>
<tr>
<th></th>
<th>CF</th>
<th>Max.</th>
<th>I. M. A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mand.</td>
<td>TF</td>
<td>TF</td>
<td></td>
</tr>
<tr>
<td>Cl I</td>
<td>4.51</td>
<td>1.76</td>
<td>2.51</td>
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<td>Cl II Div. 1</td>
<td>7.51</td>
<td>1.14</td>
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<tr>
<td>Cl II Div. 2</td>
<td>3.69</td>
<td>2.08</td>
<td>1.78</td>
</tr>
<tr>
<td>Cl III</td>
<td>2.00</td>
<td>2.06</td>
<td>0.97</td>
</tr>
<tr>
<td>Cl I A.O.B.</td>
<td>1.02</td>
<td>1.56</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Fig. 146b  Table: Index of muscular accommodation.  
(Jacobs and Brodie, 1966a)
Anterior Open Bite. The value for Class II, Division 1 was explained as being part of the soft tissue accommodation "which is associated with Class II, Division 1" involving "perversion of tongue movements and hyperactivity of the mentalis muscle which represent expression of an adequate effort to sustain oral seal during deglutition". They suggested that their findings corroborate the "general consensus that in Class II, Division 1 the upper lip is relatively functionless".

The I.M.A. as an integration of the oral vestibular forces, was found to not only reflect the vestibular pressures but also, "by an inference of adequate feedback, those exerted by the tongue". Further, they proposed that: "(1) The tendencies toward small I.M.A. values found in Class III (0.97) and Class I Anterior Open Bite (0.65) coincide with a disharmony of the vertical tier of modiolar configuration, while (2) the large values observed in Class II, Division 1 (6.59) concur with a horizontal disarray of muscle tensions."

Jacobs (1969) also stressed the element of time on muscular forces. He suggested that "all daily activity is maintained by a continuous shift or combination of various kinds of muscular performance, i.e. the dynamic, static-isometric and static-tonic performance". Only the sum of these efforts, he said, maintained over various periods of time, can be viewed as a valid criterion for determination of the balance of forces. Also "despite the fact that dynamic intraoral forces may be indeed greater than the corresponding perioral forces, the sum of all opposing muscular forces acting upon a separating body must be in balance". He suggested that the behavioural pattern of perioral and intraoral musculature must produce a condition of static equilibrium of forces. Drawing on the work of Weinstein, he pointed out that even minor muscular forces of such low values as 1.68gm, if not balanced by equal opposing forces, have been shown to be capable of moving teeth.
Indeed, the work of Winders (1956, 1958) and Kydd (1957) indicated that the contractile forces exerted by the tongue may be greater than those exerted by the lips, but Jacobs pointed out that "the lingual tonic forces may be less significant than the labial tonic forces". He suggested that perioral contractility was of secondary importance to perioral tonicity. His previous work had shown a characteristic pattern of tonic forces in various classes of malocclusion, while the pattern of contractile labiobuccal forces showed no interclass differences.

Noting that tonic forces are a function of both passive accommodation of muscle length (stretching or shortening) and active contraction, Jacobs pointed out that objective recording of tonic forces may reflect an interplay of both the motor-sensory as well as the parallel muscular mechanisms. He then suggested that tonic forces be accepted as a better index of muscular accommodation, and proposed the Index of Tonic Accommodation (I.T.A.) to be used, since its values (Fig. 147) were similar to those of the L.M.A., but it had greater clinical application.

Another author on lip activity, Posen (1972) described the activity of the perioral musculature to be far more influential on the position of the teeth than the lingual musculature, because of the fact that the tongue lies in the "mandibular trough" for much of the time while, in the case of hyperactive labial musculature, strong forces are exerted on to the incisor teeth leading to their lingual inclination. What is the case for bimaxillary dento-alveolar protrusion, he asked? The lips in this instance are parted and do not have the same effect on the teeth. He then studied the maximum perioral and lingual forces acting on the incisor teeth and attempted to explain their influence.

As for the role of the tongue, he concluded that the tongue, in normal function as in deglutition and speech, "does not exert a force strong enough in
Comparison of IMA and ITA scores in various classes of malocclusion.

<table>
<thead>
<tr>
<th>CLASS OF MALOCCLUSION</th>
<th>IMA¹</th>
<th>ITA²</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.44</td>
<td>1.79</td>
</tr>
<tr>
<td>II/1</td>
<td>6.33</td>
<td>4.59</td>
</tr>
<tr>
<td>II/2</td>
<td>1.77</td>
<td>1.48</td>
</tr>
<tr>
<td>III</td>
<td>0.96</td>
<td>0.87</td>
</tr>
<tr>
<td>OPEN BITE</td>
<td>0.63</td>
<td>0.60</td>
</tr>
</tbody>
</table>

¹ Index of Muscular Accommodation
² Index of Tonic Accommodation

Fig. 147 Table: IMA and ITA scores in various classes of malocclusion. (Jacobs, 1969)
an anterior direction to overcome the containing force of the lips or other factors such as occlusal contact, length of roots, etc.". For the role of the lips he found that the labial musculature did not seem to be strongly controlled by hereditary factors, "as is often assumed". He advocated that the teeth could be moved into positions of normal relationship at an early age and thereby overcome a strong genetic force exerted by the musculature.

For bimaxillary dento-alveolar protrusions he felt that there was a definite association of weak perioral musculature and relatively normal tongue pressure. Other malocclusions were also described in terms of muscle, and in particular, labial influences. However, the conclusion from his studies most pertinent to this discussion was that he felt there was "strong evidence that the role of the tongue in determining the final position and angulation of incisor teeth is minimal, except in those patients where there is a perverted tongue position either during deglutition or at rest".

Wilson (1975) described the previously unclear picture of the anatomy of the mentalis muscle and its clinical significance. He found that it has no direct effect on the lower lip but indirectly forces it upwards. Importantly it has a marked influence on the incisors, especially in Class II, Division 2 and Class II, Division 1. He found that any "object within the environment of the mentalis will have a greater force exerted on it than an object within the environment of the orbicularis oris. Thus the upper central incisors of a Class II, Division 2 case, and the lower incisors of a Class II, Division 1 case would be more likely to be retroclined due to its influence. It would seem that it presumably would be able to override the counterbalancing forces of the lingual musculature in such cases.

On the same subject, Simpson (1976) found that the mechanism of sealing the lips seems to depend on the activity of the mentalis muscle pushing
the lower lip upwards. He also found that when, in the presence of an incompetent lip seal, the lips were approximated, not only an increase in muscular activity of the mentalis but also of the suprathyroid muscles was recorded. This resulted in a postural change in the tongue anteriorly. This postural change was considered to be a tongue thrust.

The work of Frankel (1980a) substantiated these findings. It appeared to him that the activity of the suprathyroid muscles met the criterion of a "compensatory function" more than a bad habit, as had previously been accepted by some. He noted that when the orbicularis oris is not capable of producing a competent lip seal, other orofacial muscles must operate to compensate for this failure. "Thus the activity of the mentalis and suprathyroid muscles must be considered more an auxiliary function."

Frankel felt that the evidence presented to that date on posture of orofacial muscles pointed toward tongue thrust being more likely an effect rather than a cause of malformations. From his work on open bite cases with function regulators (FR's) in which he claimed that the tongue posture and movements were "not inhibited in any way", he suggested that the tongue was not a primary factor in causing open bite. It would seem, however, that any amount of metal connectors placed on the lingual surfaces of the dentition would surely have some effect on tongue posture. He went on to say that he thought that it still may have a causative role, but only in a secondary capacity, in the sequence of events causing physiological disorders in the orofacial complex.

Ingervall and Janson (1981) used the "pommeter", as described by Posen (1972) to measure lip strength. They found that the error in the method of its use to be high. This meant that the reproducibility and therefore the reliability of the measurements was low. These authors found a lack of any
correlation between lip strength and morphology of the lips or dentoalveolar cephalometric variables. This finding was in contrast to those of Posen. Overjet, overbite, and incisor inclination were not found to be correlated to lip strength as measured with the pommeter. They also mentioned that it was unclear what the lip strength recordings really measured. It could not be assumed, they pointed out, that lip strength reflects the tone of the lips and thereby the forces acting on the teeth. Drawing attention to the findings of Proffit, they reinforced the new concept of the equilibrium theory that it is not the balance of muscle forces acting on the dentition from both lingual and bucco/labial directions. Instead, it is the influence of other forces that influence the position of the teeth. All in all, they found the clinical value of lip strength measurement to be very limited. "This" they suggested, "may be due to difficulties in recording lip strength with simple methods or to a small influence of lip strength on the dentition."

Frankel (1980b) believed that the postural pattern of the lip and perioral musculature is the major essential factor in the establishment of physiological conditions in the whole of the orofacial area. He based this belief on the "morphological alterations in the dentition and skeleton resulting from lip seal training alone". The lip seal training, related to anterior open bite malocclusion, consisted of the vestibular devices used on the Function Regulator. He concluded that the tongue could not therefore be the primary factor in causing anterior open bite.

Studies by Lowe (1980, 1983) on tongue and lip resting pressures have added to the understanding of their influence on dental arch form and tooth position. He found a "highly significant correlation coefficient between the genioglossus muscle threshold and overbite" suggesting that tongue postural activity may exert a definite influence on incisor position. With regard to balance in the vertical plane and to open bite, he found that low thresholds for
the genioglossus muscle were related to undererupted maxillary and mandibular
central incisors. He surmised that "since teeth normally erupt until they
contact something, anterior open bite malocclusions may be due to the
impeded eruption of anterior teeth as a result of a forward tongue posture".
Another finding of interest was that his study did not confirm the "theory" of
Proffit (1978) regarding lip posture activity being an important factor in the
determination of incisor position. The postural activity of the orbicularis oris
muscle did not correlate with the craniofacial variables he measured. He
found however, positive correlations between genioglossus and masseter muscle
activity and these craniofacial variables, suggesting then that they may be of
significant clinical importance.

Owman-Moll and Ingervall (1984) in studying the effect of the clinical
use of vestibular screens found that in denying the mandibular incisors the
influence of the labial musculature, the mandibular incisors tended to procline.
This they attributed to the "influence of forces from the tongue". They also
cited the findings of Bjerregaard, Bundgaard, and Melsen (1980) who found this
effect in their studies on lip bumpers.

On the surface these findings would seem to support the old concept
of equilibrium, but in the light of previous studies, other factors are clearly
involved.

4.2.1.5 Reliability of Equilibrium Theory Research

Just how seriously can the force measurements of the tongue and
perioral tissues be taken?

A study by Christiansen, Evans, and Sue (1979) investigated: (1) The
lateral pressures of the resting tongue in the region of the mandibular canines
and premolars at a point equal to, and also less than the intercanine distance width in subjects having either normal occlusion or open bite malocclusion; and

(2) The relationship between the area of the sensor and the measured levels of force and pressure. They concluded:

1. The normal relaxed tongue produces a very low force against the lingual surfaces of the mandibular dentition;

2. The level of lingual force in patients with a dental open bite malocclusion was found to be similar to that of normal subjects;

3. Resting lingual forces increase rapidly as tongue width is decreased by the force transducer; and

4. Whenever force recordings are reported in myometric studies, the size of the sensor area should also be given to specify pressure levels.

As these authors point out, that the lingual pressures in subjects with open bite are essentially the same as in control subjects, may seem unusual when considering the resting pressures of the tongue as a cause for the open bite malocclusion. Pressures were actually less than the normative values when open bite prevailed. However, as they stress, "other factors such as differences in tongue position may be present without affecting force levels"; a most important point it would seem in relation to the methods used for measuring lingual pressures. "The lack of a striking relationship between tongue pressure, anterior open bite, or its absence suggests that the morphology and functional environment are in balance." This seems to support the concepts put forth by Weinstein et al. (1963) regarding "equilibrium", "equilibrium position", and their stability or instability.

Also of great significance was the conclusion regarding the method of recording force levels - Conclusion 4. This has been the only accurate evaluation of the method of measuring these lingual forces (Fig.148). How
Fig. 148 Contact of lingual tissue with sensors of different diameters. The effect of the tissue surrounding the sensor becomes more important when the diameter of the sensor is small. (Christiansen et al., 1979)
much of an influence are the recording instruments? This study showed that they played a significant role. It might be said from this that any method used in oral myometric studies, to date, tends to have too great an interfering influence on the normal function of the muscles being measured. Thus the results could be left open to too much interpretation which could be misleading. As these methods improve we are likely to get results that are more compatible with the function being examined.

Proffit and Norton (1970) also noted that data for lingual pressure must be regarded with some suspicion because of the possibility of "physiologic reactance".

Jacobs (1969) also warned that "a clinical determination of static equilibrium is extremely difficult for a number of reasons: (1) Muscular force-systems encompass at least three levels of muscular performance, i.e., the dynamic, static-isometric, and tonic performance; (2) the magnitude, direction and the point of application of oral muscular forces are not easily determined, and (3) muscular forces do not represent a steady-state condition and, in fact, a great variety of force-time relationships can be observed. Consequently, quantitative measurement of oral muscular forces must be viewed as a gross approximation only."

With these limitations in mind Jacobs then discussed the merits of the available clinical tools which can be employed for measuring muscular forces, i.e., electromyography (EMG) and electrodynamography (EDG). He concluded by pointing out that EMG methods may easily lead to proliferation of conjectures as to the pattern of muscular behaviour, and EDG techniques which employ strati-gauge transducers to convert mechanical energy to electrical energy report their results in grams. However the correct unit of
force here is the dyne, which belongs to the centimeter-gram-second system and therefore includes a time dimension. He mentioned then that "various theories advancing balance or imbalance of labiolingual forces on the basis of strain-gauge measurements of muscular effort must be approached with great caution".

This concept of the inadequacy of strain-gauge measuring methods was recognised by Thuer, Janson, and Ingervall (1985) who took simultaneous recordings of lip pressure (using an extra-oral pressure transducer) and lip muscle activity (using electromyography) in subjects when their lips were in the rest position, and during chewing and swallowing. This method appears to be more reliable and less invasive; however, an evaluation of the actual technique is yet to be made.

4.2.1.6 Clinical Application of the Theory

It is interesting to note that recent authors (Mischler and Delivanis, 1984) are still quoting equilibrium concepts formulated years ago that have since been seriously questioned and/or superseded: "Rogers, Strang, and others have shown that the muscles surrounding the dental arches dictate the individual's arch dimensions; therefore, muscle balance plays an important role in orthodontic treatment and retention."

As Christiansen et al. (1979) point out, the relative importance of strong, intermittent forces compared with weaker, but constant, resting forces in maintaining dental equilibrium "is of more than casual interest in clinical situations". The treatment, they suggest, of speech and swallowing abnormalities such as tongue thrusting and the prevention of relapse after orthodontic or orthognathic surgical treatment would have a more rational basis if the identification or nature of the forces and other variables involved in dental equilibrium were understood.
Weinstein (1967) quoted the work of Harman (1966) who found that "a tooth moved from its original position of stable equilibrium by an external force, even one of very low magnitude, tends to return to its original position upon removal of the external force".

Another relevant aspect (Godfrey, 1985) is that it is difficult to discuss 'equilibrium theory' in toto, for otherwise we would have to predict and demonstrate that environmental forces did not influence tooth position, or that positions of teeth are continually changing by substantial amounts.

To recapitulate, the fundamental tenets of the equilibrium hypothesis as restated by Weinstein et al. (1963) are these:

1. Each unit of the dentition is in equilibrium with its surroundings at any instant. The surroundings must be considered as a whole, that is, they must include adjacent teeth, the tongue, the buccolingual musculature, the bone and intervening periodontal ligament, and the occluding teeth or interposed matter. In enumerating elements surrounding individual teeth, consideration must also be given to foreign objects, i.e., thumb, fingers, orthodontic appliances, etc.

2. The equilibrium position of a tooth will be one for which the effects of those random forces, which form a consistent pattern of application to the crown area, will be self negating. That is, the effect of such forces that would tend to permanently displace a tooth in a certain direction will be counteracted by the effects of forces tending to displace the tooth in the opposite direction.

3. If there is superimposed on the crown of a tooth, which is in an equilibrium position, a system of forces the resultant of which is zero, it is hypothesised that the tooth in question will in time be permanently displaced to a location which satisfies the requirements of an 'equilibrium position' as above.
Perhaps the real test of validity of equilibrium theory lies in its effects on or results of orthodontic treatment. This is seen most evidently in orthodontic treatment relapse. Most cases of well treated orthodontic patients tend to show a successful, stable result. However, what of those cases, for example anterior open bite corrections, in which relapse occurs? Kydd et al. (1963) found that of these individuals, those exerting three times the tongue pressure to lip pressure had relapsed to an anterior open bite.

Vig (1975) tells us that "in a high proportion of such cases, following the removal of retention the incomplete overbite is re-established". He attributes this phenomenon to encroachment of orthodontic treatment on the patterns of soft tissue behaviour. Obviously then in these instances the new equilibrium position of the teeth is unstable, unless other steps are taken to attend to the patterns of soft tissue behaviour. Recent research by Lopez-Gavito, Wallen, Little, and Joondeph (1985) tends to support this concept. They found, among other things, that more than 35% of the open bite patients studied showed a post-treatment relapse of 3mm or more. Also, that the lower incisor vertical position was consistently depressed in the relapse cases, indicating the probable encroachment on deviant lingual behaviour.

Watson (1982b) seems to have summed up the general feeling regarding the latest findings on equilibrium theory: "If we know or find out what kind of stress distribution we want to alter in order to get the morphological changes we desire or the type of muscle activity that controls it and how to engage those muscles in that activity, orthodontics will be a new game."

It seems that from the foregoing discussion, two aspects stand out. Firstly, that the technology used to measure the oral "stress distributions" are still highly unsatisfactory to be making definite conclusions regarding muscle
pressure relationships. Secondly, that as far as this discussion goes, the significance of tongue function lies in its resting posture rather than its functional movements, and that of the two pressure patterns, lingual versus perioral, the lingual appears to have a greater influence.