

The effect of extra-oral traction : a review

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Abstract

The application of force to bone has been shown to produce a change in its shape or morphology. This paper reviews the literature relating to the principles of such force application by extra-oral appliances to the maxilla and mandible both in animals and humans. The significance of direction of force, amount of force, and timing of force application is stressed. Studies of craniofacial changes associated with the use of face-bows and cervical straps in orthodontic treatment are closely examined. The post-treatment changes, after the extra-oral forces have been discontinued, are also discussed.

Key Words: Extra-oral traction, headgear, chin-cup.

INTRODUCTION

Cranial deformations induced by external pressures verify that bone may be deformed by force application. Perez-Martinez (1960) illustrated a variety of deformed craniums in the Guanes Indians of Colombia. Another example of the results of force application to growing bones is the shortening of feet of Chinese women effected by binding (Weinmann & Sicher, 1955).

Within the craniofacial skeleton, prolonged heavy force produced by Milwaukee brace therapy produced severe, adverse changes some far removed from the actual area of force application. Some of these changes, were reported by Alexander (1966) and the effects on man and monkey have been summarized by Cutler et.al (1972). These were a reduction of vertical facial height, forward and upward rotation of both maxilla and mandible, decreases in both gonial and mandibular plane angles, resorption of lower border of mandible, increased apposition of bone at the gonial angle, and elevation of the palatal plane.

There is also evidence of an orthopaedic effect of whole bone movement resulting from force application in experimental animals. Dramatic combined changes in skeletal or whole bone movement (orthopaedic) and teeth and alveolar bone movement (orthodontic) have been demonstrated in monkeys from the use of heavy continuous extra-oral forces, (Droschl, 1973; Elder & Tuege, 1974; Meldrum, 1975 & Brandt et.al, 1979). Severe midfacial depression has been shown by Droschl (1973) and Sproule (1969) resulting principally from backward and downward rotation of the naso-maxillary complex.

In contrast to the concept of external force application interfering or altering bone morphology, long bone growth has been arrested in young dogs by placing a loop of wire, or staples across the growing epiphyseal plate of the femur, tibia or radius (Gelbke, 1951 & Haas,

1948). Associated with this surgical stapling procedure no compensatory increase in girth or mid-bone diameter of the long bones was noticed. Utilization of this experimental phenomena was seen clinically when Blount and Clarke (1949) placed staples across the epiphyseal plates to arrest the growth of the femur or tibia to equalize limb length after poliomyelitis in children.

Literature surveys confirm that mechanical forces can deform bone, but of interest to orthodontics is whether the kind of extra-oral forces used in clinical practice, may modify the shape of the facial skeleton? An important element of this question is whether maxillary or mandibular growth can be retarded or redirected and whether the induced changes are significant and permanent?

CLINICAL APPLICATIONS

The Effect of Extra-oral Forces on the Maxilla

(i) Distal Tooth Movement:

Distal movement of upper molar teeth resulting from the use of extra-oral traction appliances has been demonstrated in many studies, for example Klein, 1957; Moore, 1959; Wieslander, 1963/74 and Mills et.al, 1978.

Distal movement of molar teeth has been shown to be either by tilting or a bodily movement, both with cervical traction (Wieslander, 1963 and Melsen, 1978) and also with occipital straight-pull headgear (Gianelly & Valentini, 1976 and Bernstein et.al, 1977). Klein (1957) found direction of force application was important with cervical traction. Distal tilting of upper molar teeth occurred when the outer bow of the cervical gear was tilted downwards and distal bodily movement with the extra-oral bow tilted upwards.

Poulton (1967) showed that tilting or bodily movement may be achieved, depending upon the headgear design and resulting force application. Distal bodily movement may be induced by using

a combination of high-pull traction and cervical traction (Badell, 1976).

(ii) Extrusion of Molar Teeth

Extrusion of molar teeth was reported in some studies of cervical traction (Klein, 1957; Wieslander, 1963 & Melsen, 1978). Teeth extrusion seemed to occur whether the extra-oral bow was tilted upwards or downwards (Klein, 1957 and Melsen, 1978). On the other hand Mills et.al (1978) found that the cervical face bow with J hooks withheld the normal downward and forward eruption of the maxillary first molar. Badell (1976) observed intrusion of upper molars with the combination high and low pull headgear.

(iii) Movement of Incisor Teeth

Lingual movement of upper incisor teeth as a result of maxillary extra-oral traction therapy has also been reported (Ricketts, 1960).

Retraction of lower incisor teeth was in association with upper arch traction observed by Ricketts (1960) and Ringenberg & Butts (1970). Ricketts (1960) believed that lower incisor retraction may have been due to lingual tipping of upper incisors impinging on the lower teeth.

(iv) Movement of Maxilla

Many studies have shown that Point A moved distally as a result of cervical traction therapy (King, 1957, and Klein, 1957) and from a combination of cervical and occipital anchorage headgear (Bernstein, 1976). In contrast to these reports no significant change in Point A was found by Badell (1976) and Bernstein et.al (1977), but these treatments were for approximately four months.

A reduction of the SNA angle under headgear therapy has been widely reported by King (1957); Klein (1957); Melsen (1978).

This reduction occurred by the Anterior Nasal Spine of the maxilla (ANS) moving posteriorly, Ricketts (1960). Wieslander (1963, 1974a) also showed that ANS descended more vertically. Conflicting evidence suggests that extra-oral traction does not affect ANS position (Bernstein et.al, 1977 and Moore, 1959). Mills (1978), who used cervical traction with J hooks, found that neither ANS or PNS descended during treatment.

A decrease in the maxilla/mandible relations adjudged from the ANB angle has been reported in several studies (Sandusky, 1965 and Mills et.al, 1978).

In contrast to the effect only on Anterior Nasal Spine (ANS) a tipping down of the anterior part of the palatal plane was also reported from use of cervical headgear (Klein, 1957 and Wieslander,

1963, 1974a). No significant change in the palatal plane was found when using cervical headgear with J hooks (Mills et.al, 1978) or using a combination high-pull and cervical traction appliance (Badell, 1976). That a tipping up of the anterior part of the palatal plane could be induced was shown by Brandt et.al (1979) who used a maxillary cast splint attached to occipital and parietal anchorage headgear on adult monkeys.

(v) Occlusal and Orthopaedic Effects

A tipping down of the anterior part of the occlusal plane was shown in some studies (Ricketts, 1960; Mills et.al, 1978) whilst others have reported that the occlusal plane remained stable (King, 1957 & Klein, 1957) or even tipped up anteriorly with different mechanotherapy (Brandt et.al, 1979).

The more profound orthopaedic effects of extra-oral appliances on the maxilla have also been reported. These varied from posterior movement of the pterygomaxillary fissure (Ptm) (Bernstein, 1976 and Wieslander, 1963, 1974a), clockwise rotation of the sphenoid bone (Sandusky, 1965 and Wieslander, 1963, 1974a), Posterior rotation of the entire maxillary complex (Melsen, 1978 and Ringenberg & Butts, 1970) and a combined superior posterior displacement of the maxilla with a combination headgear (Brandt et.al, 1979).

Principally tooth movement took place and very little orthopaedic effects were demonstrated in studies in which treatment time was brief (Badell, 1976; Bernstein et.al, 1977; and Gianelli & Valentini, 1976).

(vi) Effect on Mandible of Maxillary Change

Extra-oral force directed to the maxilla may cause changes in the relationship of the mandible, which may be undesirable (Poulton, 1967; Ricketts, 1960). An opening of the mandibular plane angle has been reported by Sandusky (1965) and Mills (1978). A sex variation in response was shown by Blueher (1959) when the mandibular plane angle increased in girls but stayed the same or decreased in boys. Different criteria of assessment of changes in maxillo mandibular relations showed varying changes, a slight downward and backward rotation of the mandible (Melsen, 1978), an increase of the Y-axis angle (Klein, 1957; Ricketts, 1960) found an increase in the X-Y axis angle in cases with both prognathic and retrognathic tendencies of the mandible.

In spite of undesirable associated mandibular changes, facial convexity tended on the whole to decrease in spite of the Y-axis angle opening (Klein, 1957 and Ricketts, 1960).

The downward and backward rotation tendency of the mandible as a result of cervical traction is reflected in decreases in SNB (Mills et.al, 1978), SNPog. (Melsen, 1978) and increases in anterior facial height (Ricketts, 1960 and Sandusky, 1965). That there appears to be no consistent pattern for SNB reduction was shown by Blueher (1959).

The Effect of Extra-oral Traction on the Mandible

Many orthodontists believe that the chin-cup inhibits mandibular growth, however direct evidence of mandibular growth inhibition in humans has been questioned (Armstrong, 1961).

(i) Effect on Incisor Relationship

The chin-cup appears effective in correcting some Class III incisor relationships, however the lower incisors become more retroclined and the upper incisors more proclined (Armstrong, 1961/63; Thilander, 1963/65; and Vego, 1976). In contrast to these studies (Graber, 1977) found these identical changes in an untreated group, i.e. lower incisors became more lingually inclined, whereas with chin-cup therapy the mandibular incisors showed a relative labial inclination and Graber concluded that the anterior crossbite correction took place as a result of orthopaedic changes.

(ii) Effect on Mandibular Position with Chin-cup Therapy

An improved molar relationship has been demonstrated (Armstrong, 1963; Thilander, 1963/65 and Vego, 1976).

A reduction of the SNB angle as a result of chin-cup therapy has been shown by Thilander (1963) and Graber (1977). However some reports show no significant change in the mean SNB angle (Armstrong, 1963).

(iii) Inhibition of Mandibular Growth

Animal studies have shown that mandibular growth can be altered and retardation of condylar growth has been reported (Janzen & Bluher, 1965, Graber, 1975, and Petrovic et.al, 1975). A decrease in the mandibular plane angle (Janzen & Bluher, 1965 and Petrovic et.al, 1975) and a closure of the gonial angle and increased antegonial notching has also been reported (Janzen & Bluher, 1965).

In some human studies, no confirmatory evidence of alteration to mandibular growth has been reported (Armstrong, 1961/63). Thilander (1963) found no change in condylar growth or difference in posterior ramus height during the treatment period. In contrast to these reports, a decrease in the mandibular plane angle (Graber et.al. 1968/77, Vego, 1976), a closing of the

gonial angle (Thilander, 1963/65; Vego, 1976, and Graber, 1977), and a backward rotation of the mandible (Thilander, 1967/65 and Graber, 1977) have been reported.

Graber (1977) reported a retardation of vertical ramus growth of the posterior aspect of the mandibular body, and the posterior of the maxilla; there was also a decreased amount of antero-posterior growth of the anterior cranial base and less opening of the cranial base saddle angle in a treatment group compared to a control group.

Graber et.al (1968) illustrated one case with an anterior open bite and this was treated using vertical-pull headgear in conjunction with the chin-cup and it was suggested that treatment induced the depression of posterior molar segments.

Recovery After Removal of Extra-oral Forces

Logan (1968) stated that after removal of the Milwaukee brace, 'growth normal to the individual is resumed at an accelerated speed when the inhibiting pressure is removed' (ibid, p. 204, Figures 1 and 2). Cutler et.al (1972) also found that in growing monkeys, dimensional changes which occurred with the Milwaukee brace tended to relapse when the brace was removed. Teeth tended to return to their original positions and axial inclinations, there was a tendency for the lost vertical dimension to recover and for normal condylar growth to resume (Cutler et.al, 1972 and Logan, 1968). Gelbke (1951) also showed that when mechanical forces were removed from femurs of dogs before skeletal maturation took place, changes were partly reversible.

Melsen (1978) examined post-treatment changes after cervical headgear was discontinued and found that while the maxilla moved backward and downward during treatment, the

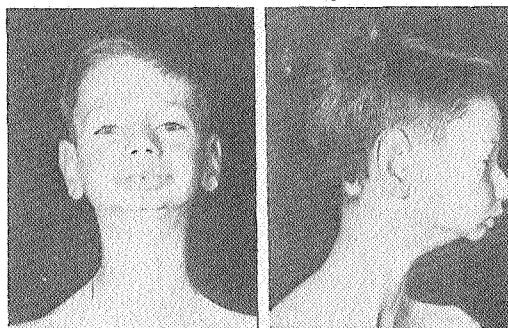


Figure 1 — from Logan (1966) Page 199, by kind permission of the publishers.

'November 1964 aged 10 years. Showing maximal deformity. The patient spent 3 years in a Milwaukee brace; 8 months in a localiser jacket and 5 months subsequently in a Milwaukee brace between the ages of 6 and 9 years'.

maxilla 'changed dramatically' (ibid, p. 537) to a normal forward and downward direction post-treatment and suggested that 'the influence of cervical treatment on the growth pattern of the facial skeleton is only temporary. The maxillary complex will later catch up with the amount of growth that could normally be expected and observations on the mandibular rotation imply the same development' (ibid, p. 537).

Other authors have shown that at least some of the effects of extra-oral traction therapy do remain stable. Poulton (1964) showed that the treatment effect of headgear on upper incisors and molars was not all lost and the slight relapse post-treatment could be explained by excessive tipping of incisor teeth and stressed the importance of the continued use of headgear during the retention period. Mills et.al (1978) found that the ANB angle reduction including the with-holding effect on the SNA angle proved stable, although PNS position and distal tipping of upper molars relapsed. The downward and backward rotation of the mandible was also maintained post-treatment, although mandibular growth returned to more normal pattern after treatment. Wieslander (1974b) confirmed that the effect of cervical treatment is quite stable, including distal movement of maxillary molars, changes in Point A, Ptm, and rotation of the sphenoid bone.

Thilander (1965) found that relapse occurred in some successfully treated cases after chin-cup therapy was discontinued. A small overbite and large mandibular plane angle initially seemed to increase the risk of relapse.

DISCUSSION

Experimental evidence shows that dramatic orthopaedic and orthodontic changes occur not only in growing monkeys but also in adult monkeys, as a result of continuously applied extra-oral forces against the maxilla (Droschl,

1973; Elder & Tuenge, 1974; Meldrum, 1975 and Brandt et.al, 1979).

There may be several reasons why in humans the orthopaedic changes which occur may be relatively small. Treatment tends to be discontinued when Class I molar relationship is established (Gianelly & Valentini, 1976 and Bernstein et.al, 1977). In animals distal tooth movements are not limited and therefore forces may be applied for longer periods. Also the forces were applied continuously in monkeys, while they are usually used intermittently in humans; the force magnitudes relative to body weight were usually much higher in monkeys than those conventionally used on patients. For example, Droschl (1973) calculated that the 100 gms of force applied per side on a 400 gm monkey represented an equivalent force in man, of 7 to 8 kg per side.

Orthopaedic changes occur in humans also as a result of 'heavy' interrupted forces against the maxilla but the magnitude of these changes is very small compared to the tooth movement which takes place. (Gianelly & Valentini, 1976 & Poulton, 1967.) Tooth movement is rapid in humans and there is not enough time to achieve appreciable orthopaedic effects. For example in a 6 mm discrepancy, frequently tooth movement achieves 3 mm and orthopaedic correction 3 mm. This later is only 3 per cent of a 100 mm mid-facial depth dimension (Gianelly & Valentini, 1976). Bernstein et.al (1977) found only 1 mm distal movement of the maxilla in a patient in whom 6 mm distal molar movement was recorded. Orthopaedic correction may be important in the correction of certain convex, skeleto-dental malocclusions, but frequently tooth movement is the principal mode of correction, (Gianelly & Valentini, 1976).

Although orthopaedic effects on deeper maxillary structures have been reported (Ricketts, 1960; Wieslander, 1964/74a), these changes may appear significant but usually are relatively small. For example, Wieslander (1963) observed approximately 1 mm difference between the position of Ptm in the control group and the treatment group, and this was observed over three to four years. Wieslander (1974a) has also demonstrated 1.91 mm mean difference between the position of Ptm and 1.64° difference of sphenoid rotation between the control and treatment groups.

Extra-oral forces seem most effective in younger patients particularly in the early mixed dentition (Bernstein, 1974). Thilander (1964/65) and Vego (1976) noted the largest reduction of the SNA angle in the 8-10 year age group. Sandusky (1965) found more reduction of



Figure 2— from Logan (1966) Page 200, by kind permission of the publishers.
'January 1967 aged 14 years. Showing the dento-facial rehabilitation 2.5 years out of orthopaedic braces, with the help of simple orthodontic therapy'.

the ANB angle in the younger age group (average age 10.12 years), and significant rotation of the sphenoid bone occurred only in the younger age group.

Case selection is important in achieving clinical success with extra-oral traction (Ricketts, 1960 and Sandusky, 1965) and cervical extra-oral traction appears to be not suitable for patients with retrognathic tendencies or large mandibular plane angle.

Varying opinions exist as to whether maxillary and mandibular growth can be actually retarded. Wieslander (1963) and Sandusky (1965) argued that there was no actual retardation of maxillary growth and showed significant increases of maxillary arch length with extra-oral traction. Ringenberg & Butts (1970) believed that Ptm-NS decreased significantly, indicating retardation and posterior movement of the maxilla.

Although Armstrong (1963) found no evidence that mandibular growth could be altered with a 'chin-cup', other authors did show orthopaedic effects on the mandible (Graber, 1977; Thilander, 1963/65; and Vego, 1976). Graber (1977) used relatively heavy forces (450-900 gm per side) and long treatment time (3 years), compared to Vego (1976), who used 150-300 gm per side and discontinued treatment when flush terminal plane relationship of molar teeth was established. Thilander (1963/65) also used lighter forces than Graber (1977).

Graber et al (1968) suggested that in order to achieve significant and lasting orthopaedic effects with the chin-cup, 4 lbs of force per side needs to be used and prolonged treatment times were needed, extending often from 2/3 years of age until the end of puberty.

It has been shown that if appliances are removed before growth is complete, normal growth may resume (Cutler, 1972; Gelbke, 1951; Graber et al, 1968; Logan, 1968, and Melsen, 1978) and there is some evidence that growth post-treatment may continue at an accelerated speed (Logan, 1968 and Melsen, 1978). From a clinical point of view there is evidence that in order to effect significant and lasting orthopaedic changes, it seems to be advisable to use appliances for long periods and preferably until growth has ceased. Whilst Thilander (1963) believes 'It is not reasonable to expect a child to wear a chin-cup throughout its growth period' (ibid, p. 395), there is some evidence to suggest that at least in part this opinion could be applied to other extra-oral appliances.

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