

Extra-oral retraction mechanics: a review

Keith Godfrey

Department of Orthodontics, Faculty of Dentistry, Khon Kaen University, Thailand

Objectives: The literature relating the centres of resistance of the maxillary molars, the maxillary dental arch, and the maxilla to extra-oral retraction vectors intended for both orthodontic and orthopaedic effects, is reviewed. Conventional clinical wisdom concerning the different effects of cervical, straight, and high-pull vectors is questioned.

Conclusion: Published studies lack the rigorous design necessary for unequivocal interpretation.
(Aust Orthod J 2004; 20: 31–40)

Received for publication: June 2003

Accepted: December 2003

Introduction

Some history and early developments

More than 100 years ago Kingsley is reported to have used occipital anchorage during treatment.^{1,2,3} In 1907 Angle⁴ referred to extra-oral anchorage and illustrated his occipital headgear and traction bar, which he replaced with “Baker anchorage” (intermaxillary elastics). It is worth noting that in the seventh edition of his text Angle⁴ described the use of extra-oral traction combined with extraction of the upper premolars. These examples may have been carried over from the “enigmatic sixth edition”,⁵ which Angle withdrew from distribution because it contained a number of extraction cases, and he wanted to downplay the role of extractions in treatment. In 1944 Hahn⁶ referred to occipital anchorage as a means of avoiding extraction of the premolars for Class II correction.

According to Breitner,⁷ in 1911 Oppenheim introduced the concept of the centre of rotation of a tooth as the point around which a tooth would rotate when a force was applied to the crown. Oppenheim also recognised that if a force could be arranged so that it passed through the centre of rotation then a tooth, such as a molar, would move bodily. Since such bodily movement does not involve tipping or rotation, the focal point for the force to produce this translatory movement has become known as the centre of resistance.

Kloehn^{1,8,9} apparently took up the use of extra-oral traction following a publication by Oppenheim in

1936, and must be given credit for promoting the use of cervical traction as the first phase in two-phase treatment of Class II malocclusion and maxillary anterior crowding. Phase I was concerned with distalizing the maxillary first permanent molars in the mixed dentition period. To translate the molars distally Kloehn^{1,8,9} advocated alternately tipping the molar crowns and roots. Distal crown tipping was produced by positioning the outer bow of the facebow below the centres of resistance of the maxillary molars, and distal root tipping by positioning the ends of the bow above the centres of resistance. Kloehn did not refer to a centre of rotation or resistance. He merely stated, “the face bow is bent above (or below) the arch”. It is almost certain Kloehn was unable to obtain bodily movement of the maxillary molars with a neck-strap because of the difficulty in directing an extra-oral force through the centres of resistance of the molars. He used a long outer bow with a force of 350 to 700 gm per side worn for 10 to 14 hours per day.^{1,8,9} In contrast, Armstrong¹⁰ applied 2000 gm of force per side 24 hours per day for phase I molar correction with “combi” headgear and a 2 x 4 appliance with large dimension rectangular wire. Because he wired the facebow *in situ* compliance was assured, providing the headgear was worn. Armstrong¹⁰ reported that the desired occlusal relationships could be obtained in 3–4 months, and that there were no adverse effects and no complaints from patients.

Weber¹¹ showed examples of extra-oral facebows designed to distalize the mandibular teeth:

1. A "tandem hook-up", consisting of extra-oral traction to the maxillary molars and Class III elastics to a sliding jig on a mandibular E-arch, intended to distalize the mandibular molars and regain space in the mandibular arch.
2. A facebow applied directly to the mandibular molars performed a similar task.
3. A facebow to retrocline the mandibular incisors in a Class III malocclusion in the mixed dentition.

Types of extra-oral retraction mechanics

The terminology is related to the general direction of the extra-oral force vector, but it is not standardized:

1. High-pull has been referred to as occipital-pull,¹² and parietal-pull¹³ headgear. As the term implies the force vector is directed from the occipital area.
2. Low-pull is synonymous with cervical-pull⁷ or cervical-force headgear. The force vector is directed from the neck.
3. Medium-pull is sometimes referred to as straight-pull. The extra-oral force vector falls between high-pull and low-pull, and runs parallel to the occlusal plane through the centres of resistance of the maxillary molars. It is used for bodily retraction of the maxillary molars without intrusion or extrusion. This form of appliance usually requires linking or combining separate high-pull and low-pull units to the extra-oral bow; this is the so-called combi-pull advocated by Armstrong.¹⁰
4. Interlandi headgear can perform the functions of a high-, medium- or low-pull appliance either separately or in combination.^{14,15}

Purposes/uses of extra-oral retraction

Extra-oral retraction appliances are mainly used to retract the maxillary molars and to support these molars for intra-oral mechanics, such as retraction of an anterior segment. During extra-oral retraction the maxillary molars may be: extruded or intruded, the crowns or roots tipped distally, rotated a small amount, or expanded or contracted bilaterally. To carry out these additional movements the length and orientation of the outer bow and intermolar width of the inner bow must be adjusted.^{8,9} It has been suggested that bodily movement of molars without buccal tipping can be controlled using a square, rectangular, or oval section intra-oral bow with matching

molar tubes,¹² or double-back ends to the intra-oral bow.¹³ However, the preferred method for controlling such bodily movement is to use a transpalatal arch in association with the extra-oral traction.¹²

Spontaneous distal movement of erupted and unerupted maxillary premolars occurs when the first molars are retracted with extra-oral appliances.^{10,12} This effect is a consistent outcome of extra-oral retraction, and is thought to be due to appliance-induced tension in the trans-septal fibres connecting the buccal teeth. Retraction of the maxillary molars or the entire maxillary dental arch may be facilitated by extraction of the maxillary second molars.¹⁶ More rapid retraction of the maxillary molars is likely to result if traction is applied before bone has been deposited in the second molar extraction sockets.¹⁷

The second major use of extra-oral retraction mechanics is to support the maxillary molars for incisor retraction and torque, often described as maximising or reinforcing the anchorage provided by the molar teeth.¹⁸ Distally-directed force from an extra-oral appliance has also been used to contribute additional anchorage with various functional appliances, such as modified activators,¹⁹ the Clark twin block,²⁰ the Herbst appliance,²¹ and maxillary removable appliances such as the Margolis' ACCO appliance,²² and Orton's *en masse* appliance.²³

Less common uses of extra-oral appliances are to: correct a maxillary molar(s) on one side, retract the anterior segments or canines, correct the midlines, intrude the maxillary molars and incisors, distalize the mandibular molars, and disimpact a maxillary first molar(s). For unilateral molar retraction, an asymmetrically-supported swivelling outer bow¹² and a fixed asymmetrical outer bow have been suggested. In the latter design, which is more favoured, the arm of the outer bow is longer and offset laterally on the side requiring molar retraction. All unilateral facebow designs produce sideways/lateral forces that can result in a lingual crossbite of the molar being distalized and a buccal crossbite of the contralateral molar.^{24,25} As a rule, "The magnitude of this net (component) lateral force increases as the unilateral effectiveness of the face-bow increases".²⁴

Roth²⁷ demonstrated the use of a short intra-oral bow, the so-called Asher facebow, for retraction of the anterior segment into premolar extraction spaces. This type of facebow applied force directly to the maxillary

canine brackets. Other clinicians have used J-hooks with straight-pull traction to retract both maxillary and/or mandibular canines in first premolar extraction cases. Thus, Armstrong,¹⁰ Hickham,¹⁴ and Vaden *et al.*¹⁸ have used four J-hooks with the Interlandi headgear to simultaneously retract maxillary and mandibular canines. Hickham¹⁴ also suggested the use of diagonally set J-hooks for reciprocal correction of maxillary and mandibular centre lines. J-hooks have also been used with high-pull headgear for intrusion of either the maxillary molars or the anterior segments. However, it is difficult to control the line of action of J-hook traction, and to relate the line of action to the centre of resistance of a particular tooth or dental arch segment. Application of J-hook traction to the anterior segment in a full labial arch appliance does not give simultaneous control of the posterior segments, especially at the molars. Finally, Bjerklin *et al.*²⁸ used extra-oral retraction to disimpact ectopic mesio-angular maxillary first molars.

Location of the centres of resistance and extra-oral force vectors

As noted above, the concept of a centre of resistance can be traced back to Oppenheim although he referred to a centre of rotation only.⁷ It has been suggested that the centre of resistance of a maxillary first permanent molar is situated at the trifurcation of the roots, but this is almost certainly an oversimplification because external factors, such as contact with adjacent teeth, alter the centre of resistance. For example Worms *et al.*²⁹ reported that distalization of the maxillary first molars led to occlusal and distal movement of the erupting second molars. It would appear that the second molars resist distal movement of the first molars and, as a result, the centres of resistance of the first molars move from the root trifurcations towards the crowns. This finding has been confirmed by Dermaut *et al.*³⁰

In the case of a maxillary dental arch fitted with a fixed labial appliance the centre of resistance is thought to lie between the roots of the first and second premolars.³¹ Melsen *et al.*³² assumed that the combined centre of resistance of the four maxillary incisors would be geometrically positioned within the region of the previously identified centres of resistance in the roots of the central and lateral incisors, whereas Vanden Bulcke *et al.*,^{33,34} found the centre of

resistance was more distally placed in a "macerated" skull. Pedersen *et al.*,³⁵ using autopsy material, established that the centre of resistance of the four maxillary incisors was in a similar position to that reported by Vanden Bulcke *et al.*^{33,34} Other disagreements have been reported for the centre of resistance of the six maxillary anterior teeth. Melsen *et al.*³² estimated that the centre of resistance of the six maxillary anterior teeth was the centroid of the triangle linking the centres of resistance of the central and lateral incisors and the canines. On the other hand, Vanden Bulcke *et al.*^{33,34} found it was distal to the second premolar root, and Pedersen *et al.*³⁵ reported that it was between canine and first premolar roots. These studies attempting to determine the centres of resistance of selected teeth have used dried skulls.^{30,36–40} Only the study of Pedersen *et al.*³⁵ determined the centres of resistance using human autopsy material. Because of methodological differences associated with the different studies, most reports have included cautions about transferring the reported locations of the centres of resistance found on dried skulls to human beings.

The location of the centre of resistance of the maxilla or naso-maxillary complex is also disputed. Nanda and Goldin¹⁵ reported that it was located in the central part of the zygoma in primates, which Stockli and Teuscher³¹ asserted applied in man also. However, Billiet *et al.*⁴¹ could not distinguish the centre of resistance of the maxillary dental arch from that of the naso-maxillary complex. Tanne *et al.*⁴² reported that the centre of resistance of the naso-maxillary complex occurred at the pterygo-maxillary fissure, but others^{36–40} have reported difficulties in locating the centre of resistance of the naso-maxillary complex. In the latter studies high-, horizontal-, and cervical-pull traction to a maxillary dental splint resulted in an unexpected and variable, distal and downward displacement of the maxilla, suggesting that other factors, such as the restrictive effects of the circum-maxillary sutures, may modify the response to an extra-oral force. Thus, prediction of the effects of extra-oral traction on the maxilla is difficult.

A number of factors may affect the precise locations of the centres of resistance of the maxillary molars, and make it difficult to predict the outcome of extra-oral traction, whether it is used to distalize the maxillary molars or the naso-maxillary complex. Some of these factors are:

1. Contact between the maxillary first molar and the maxillary second molar may result in the centre of resistance moving occlusally from its position at the trifurcation of the molar roots.^{29,30}
2. The skeletal and dental morphology.³⁶⁻³⁹
3. Age and, possibly, gender differences in bone density. Many *in vitro* and *in vivo* studies have used adult skeletal material.^{37-39,41}
4. Difficulty in maintaining the headgear in a constant position, which must cast doubt on the validity of cephalometric studies to determine the centres of resistance from analyses of tooth and bone displacements in subjects. For example, Samuels and DiBiase⁴³ and Hickham¹⁴ reported that tension from a cervical strap was affected by head position.
5. The type of appliance and the type of traction used.
6. The degree of flexibility of fixed labial archwires. Vanden Bulcke *et al.*^{33,34} reported that a rigid occlusal splint/labial archwire was essential for translation.
7. Variations in the length of the outer-bow.
8. The amount of force used.
9. Expansion or contraction of the inner bow.

Several modifications have been suggested to improve the control of extra-oral traction forces. For bodily movement with straight-pull extra-oral traction, Andrews⁴⁴ suggested that the molar tubes should be placed at the gingival margins close to the centres of resistance of the molars. Several authors have analysed the effects of varying the length and angulation of the outer bow, and the relationships of the extra-oral force vectors to the estimated centres of resistance of the maxillary molars, the maxillary dental arch, and the naso-maxillary complex.^{3,12,29,31,45,46} This relationship is considered to be important for producing planned changes, whether it is to move the molars bodily, change the antero-posterior cant of the occlusal plane, or displace the maxilla.

In practice bodily movement is difficult, if not impossible, to carry out because of the play of the inner bow in the molar tubes, and flexing of the inner and outer bows of a face-bow.¹² However, the loose fit of the inner bow in the buccal tubes enables the inner bow to be inserted easily by patients.^{28,47,48} Reinforcement of the inner bow, where it joins the outer bow, does not prevent the complete bow from flexing. As a rule face bows with long arms flex more than face bows

with short arms. This play and flexing can tip the molars and affect the anterior arch segment if a fixed labial arch is *in situ*. The effect on the anterior segment can be used to produce desired changes, such as intrusion or extrusion.

Because a centre of resistance is influenced by a number of factors, a clinician must rely on his/her experience and knowledge of the effectiveness of various extra-oral appliances in producing planned changes. Progress should be monitored carefully, and the orientation of the facebow adjusted to obtain the desired effect.⁴⁹ As mentioned above, the maxillary molars can be translated distally by alternately tipping the crowns and roots,^{1,8} but to avoid changing the cant of the occlusal plane this method should not be used in arches with a fixed labial arch.

Extra-oral force

"Light", "medium", and "heavy" forces are meaningless terms without reference to the amount of force used, and the intended purpose of the appliance. The same force level should not be used in every case, but will depend on the number of teeth involved, and whether it is for orthodontic or orthopaedic movement. Although the discussants at the Round Table on Extra-oral Force² differed in their interpretations of "light" and "heavy" forces, they agreed that "heavy" forces were more likely to be used to obtain an orthopaedic rather than orthodontic effect. At this conference it was suggested that a standard extra-oral force fell in the range between 400 and 700 gm, presumably 700 gm was an orthopaedic force on the maxilla.² Ricketts, on the other hand, considered a force of 150 gm was appropriate for extra-oral retraction in adults, and presumably in children as well, and 500 gm was required for orthopaedic change.⁵⁰

However, small differences in the amount and direction of force used can produce markedly different effects. For example, Ucem and Yuksel⁵¹ tested the effects of varying the force components of combi-pull to a facebow in three groups of patients: Group 1 used 150 gm force from both the upper (occipital) and lower (cervical) components of a combi-pull headgear on each side; Group 2 used 200 gm for the upper component and 100 gm for the lower component; and Group 3 used 100 gm for the upper component and 200 gm for the lower component. They reported that the molars tipped distally in all three groups, but the tipping was significantly greater in

the Group 3 subjects. Furthermore, the molars were extruded in the Group 3 subjects and intruded in the Group 2 subjects. The maxillae were displaced posteriorly in the Group 3 subjects only. The mandibular plane angle increased only 0.5 degrees in Group 3, reduced 1.7 degrees in Group 2, and was unchanged in Group 1. The reader must draw his/her own conclusions about the mechanics used since the orientation and length of the outer-bow was not given.

Patients vary in their toleration of orthodontic force. While Kloehn^{1,8,9} considered that between 350 and 700 gm of force was the most that could be tolerated, Armstrong¹⁰ used more than 2,000 gm. In a recent controlled clinical trial of phase I treatments with functional and extra-oral traction appliances, between 250 and 300 gm of extra-oral force were used, but it is not clear whether this was intended for an orthodontic or orthopaedic effect.⁵² McLaughlin, Bennett and Trevisi⁵³ recommended a similar force level of 250 to 350 gm to provide anchorage for fixed appliances. Unfortunately, not all reports on the effects of extra-oral traction mention the force used, and many reports that do give a value fail to mention whether it refers to the total force or the force per side. As mentioned above the amount of tension/force from cervical traction can be affected by changes in head position.^{14,43,54}

Patient compliance

An important aspect of using extra-oral traction is the uncertainty whether an appliance is being worn as instructed. It has been suggested that patient compliance may be improved if both parents and clinician provide motivation, and rewards are offered for evidence of use. Evidence of compliance may be an observable rate of intended tooth movement, but there are other positive indicators:^{29,55–57}

1. The patient keeps a daily diary of length of use.
2. The patient demonstrates skill in inserting the facebow (or J-hooks) and fitting a headgear or neckstrap.
3. Mobility of the teeth receiving the traction force.
4. A parent monitors and reports that the appliance is being worn.
5. An electronic timing and recording device may be incorporated into the headgear or neckstrap. This may be "open" for the patient to check as a form of positive reinforcement.⁵⁸

6. Soiled or recently cleaned neckstrap or headgear.
7. A palpable depression of the scalp beneath a high-pull headgear. A depression is more likely to be seen if the hair is cut short.⁵⁹

Conversely, some patients may be discouraged from wearing an extra-oral appliance by:

1. Actual, or reported, experience of discomfort and pain.^{60,61}
 2. Social embarrassment, if required to wear an appliance full time.⁶²
 3. Non-acceptance of an uncommon or out-of-fashion form of treatment. This is more likely to arise when teenage users compare notes on the types of orthodontic appliances they are expected to use.
 4. Lack of interest in improving appearance.
 5. A transfer of locus of control. A patient perceives that the responsibility for an action, in this case wearing a headgear, lies with another person, such as the clinician or a parent.⁶²
 6. A clinician's lack of skill in managing an extra-oral appliance.^{44,63}
 7. Ineffective monitoring of facebow use by a clinician.^{56,57,64,65}
 8. Burn-out from previous treatment.
 9. Knowledge that use of extra-oral traction is only part of two-phase treatment. This may have a negative effect similar to burnout.
 10. Frequent dislodgment, such as may occur when the long outer bow of asymmetrical headgear lies well away from the face.²⁵
 11. Reports of risk of injury if a facebow/J-hook is dislodged. If an intra-oral bow/J-hook is dislodged on one side a catapult injury to the oral tissues,^{60,66} an eye,^{67–69} or the face can result.¹⁴ Safety in use of extra-oral traction is an important concern. To lessen the risk of injury a number of devices, such as quick-release force modules and patient-controlled facebows that lock into the molar tubes, have been introduced.^{43,69–71} Hickham¹⁴ claimed that J-hooks should not dislodge as easily as facebows, but others⁴³ have disputed this claim.
- Some clinicians endeavour to counter aversive behaviours to extra-oral traction by favouring its use on young patients. For example, Bondevick⁷² suggested it was a suitable form of treatment for 10 to 12 year-

olds, but it was less suitable for 12 to 14 year-olds, and least satisfactory when used on 14 to 16 year-olds. Other means of improving patient motivation are to limit the amount of daily use,² keep the length of treatment short,¹¹ and to provide positive reinforcement by demonstrating and giving praise for progress and possible rewards.^{63,70,73} Perhaps the most important aspect of motivation is for a clinician to demonstrate absolute confidence in the effectiveness of the appliance, and to state unequivocally that it is the most acceptable form of treatment for the patient's malocclusion.

Clinically observed effects of extra-oral traction

Application of an extra-oral force of approximately 100 gm to a maxillary molar results in an immediate small displacement of the tooth in its socket, and elastic deformation of the alveolar bone (bone bending) that supports the molar.⁷⁴ The extent of the elastic deformation depends to some extent on the form of the alveolar process and the magnitude of force applied. An extra-oral force of at least 250 gm, and often up to 500 gm, may be used; the latter tends to result in more deformation.⁷⁴ Bone remodelling, which results in orthodontic movement, occurs when the extra-oral force is continued for several hours and repeated daily for a period of several months.⁷⁵

Serial lateral cephalometric radiographs and serial study casts have been used to study the effects of an extra-oral force on the maxillary molars. Serial lateral cephalometric radiographs can no longer be justified on the grounds of radiation exposure, and the accuracy of the cephalometric measurements has been questioned.^{76–79} Three-dimensional molar changes⁷⁹ and molar changes relative to specific palatal rugae,^{77–81} have been measured on serial study casts. Ashmore *et al.*⁷⁹ measured molar movements three-dimensionally during straight-pull extra-oral traction with 14 to 16 oz per side (approximately 430–500 gm) for 10 hours per day in 36 subjects with a Class II malocclusion. A full description of their method is given by Ghafari *et al.*⁸² The molar changes were measured over a 24 month period. Over this period, on average, the molars were translated distally 2.2 mm, buccally 0.9 mm, and were extruded 1.4 mm. Variations in the rate and direction of molar change were encountered with some molars moving mesially in some subjects.

Right-left differences were also reported, confirming Graber's earlier observation.⁸³ The reasons for the variations were attributed to variable use of the extra-oral appliance by the subjects, variable tissue responses,^{64,83} and to variations in the line of action of the extra-oral force to the relevant centres of resistance in different subjects.

Instantaneous changes in molars subjected to different extra-oral force systems have been studied by Yoshida *et al.*⁸⁴ They used an intra-oral electromagnetic device to measure the instantaneous changes in molar position with different extra-oral force systems. The results of this trial are of interest because they indicate the initial response by the dentoalveolar tissues. For example, high-pull traction tipped the molar crowns mesially, whereas straight-pull and cervical-pull tipped the crowns distally. All three methods also tipped the crowns buccally.

Thirty-five clinical reports of extra-oral retraction, published during the last thirty years, have been reviewed. Twenty-six studies compared the effects of extra-oral traction with other appliances, such as functional appliances, and in 18 studies the effects were compared with changes in untreated controls. However, in many of the latter studies subjects were not randomly assigned to the treatment and control groups. Randomized controlled trials of extra-oral traction have been reported by Keeling *et al.*,⁸⁵ Wheeler *et al.*,⁶⁵ and Tulloch *et al.*^{52,86} Unfortunately, their samples were too small to control the many variables associated with extra-oral forces. Furthermore, comparisons with other studies are difficult because different extra-oral appliances were used, often in combination with other appliances. Many reports fail to give details of the method, such as the type of extra-oral traction, the amount and direction of force used, and/or the period of use. Another disappointing feature is the lack of a standardized method of recording dento-skeletal change. As a result, meta-analysis is impossible and the data from these studies can be interpreted subjectively only.⁸⁷ Six of these 35 reports included follow-up results three years or longer after treatment, and none of these was a satisfactorily controlled clinical trial or randomized controlled trial. These observations suggest that orthodontists are not able to employ evidence-based best practice when using extra-oral traction.

Concerns^{26,88–90} that cervical/low-pull traction extrudes the maxillary molars and results in

permanent opening of the mandibular plane angle are unfounded. One of the earliest reports to provide evidence to contest these concerns about a permanent opening rotation of the mandible was published by Baumrind *et al.*⁴⁹ They reported that in 249 subjects who received phase I treatment by several orthodontists with cervical-, combi-, or high-pull appliances, the mean mandibular plane angle for each type of traction was not significantly different from that of untreated controls. This report by Baumrind *et al.*⁴⁹ is supported by Hubbard *et al.*'s⁹¹ analysis of 85 patients treated with cervical traction by Kloehn. However, Hubbard *et al.*⁹¹ concluded that adverse effects in phase I due to cervical traction may have been cancelled out by the phase II fixed appliance treatment. Three long-term studies with untreated controls reported no significant increase in the divergence of the mandibular plane angle, or an increased lower face height.^{26,92,93} Another five long-term studies without controls reported similar findings.^{94–98}

One important finding is that cervical- and combi-pull traction in growing patients with hyperdivergent faces results in similar antero-posterior and vertical changes.⁹⁸ Changes in mandibular plane angle were variable and two years after treatment increased only 1.5 degrees. However, mandibular opening may persist if cervical traction is used on extreme hyper-divergent Class II malocclusions, and on post-adolescent Class II malocclusions. Several reports noted that while the maxillary molars extruded during treatment the pretreatment skeletal condition returned post-treatment, apparently due to re-establishment of the original growth pattern,⁹¹ and a possible orthopaedic rebound. While there is no adequate evidence that prolonged use of extra-oral traction in adults will lead to a permanent change in the facial pattern, clinicians should be cautious.^{99–102} Adverse skeletal effects could result from protracted use of force as the classical practice of binding Chinese women's feet, the prolonged use of the old-style Milwaukee brace for the treatment of adolescent scoliosis,¹⁰³ and the progressive neck-stretching with metal rings among some isolated ethnic communities, such as in Northern Thailand, attest. It is relevant to note that Logan's¹⁰⁴ observation that the adverse effects on the craniofacial morphology and the occlusion from a Milwaukee brace were often reversed if this appliance was discontinued before the end of adolescence.

Ghafari *et al.*⁸² observed that late mixed dentition treatment followed by phase II permanent dentition treatment was just as effective as treatment in the mid-mixed dentition. Tulloch *et al.*⁸⁶ supported this view when they concluded that early phase I treatment was of questionable value unless it was to reduce risk of accidental trauma to protruding incisors. The majority view is that there are no substantial orthopaedic effects from extra-oral traction in children unless the traction is applied continuously throughout adolescence.

General conclusions

1. To obtain the desired dento-skeletal effect with extra-oral traction, the type of extra-oral appliance, facebow adjustments, amount of force used, locations of the centres of resistance of teeth and maxilla, and the craniofacial type must be considered.
2. Different subjects may respond differently to the same type of extra-oral traction.
3. Extra-oral retraction applied to the maxilla during the mixed dentition is unlikely to have any significant orthopaedic effect. However, if extra-oral retraction is applied throughout the growth period it may have an orthopaedic effect.
4. Extra-oral traction is more likely to be successful in the mixed dentition because at this age patients are more compliant.
5. A significant proportion of patients may not benefit from phase I treatment.
6. Early phase I treatment may reduce the likelihood of damage to protruding maxillary incisors.
7. Lack of, or failure to use, retention between phase I and phase II may nullify any improvement obtained phase I.
8. Use of extra-oral anchorage in the late mixed dentition period is as effective as treatment in the mid-mixed dentition, and it avoids retention problems.
9. With the possible exception of Class II patients with extreme mandibular hyperdivergency, cervical traction does not result in long-term opening of the mandibular plane angle. Following cervical traction in growing patients the mandible tends to return to its pretreatment orientation.
10. Cervical-, combi-, and occipital-pull traction have similar antero-posterior and vertical effects in growing patients.

11. Because of patient variability close supervision of extra-oral traction appliances is recommended.

Corresponding author

Associate Professor Keith Godfrey
Department of Orthodontics
Faculty of Dentistry
Khon Kaen University
Khon Kaen 40002
Thailand
Email: keigod@mail.kku.ac.th

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