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Moulding of the generate to control open bite during mandibular distraction osteogenesis

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SUMMARY Distraction osteogenesis of the craniofacial skeleton has become a widely accepted, safe, and effective means of craniofacial reconstructive surgery. Despite excellent results in general, there are still some uncertainties related to the procedure, such as development of an anterior open bite (AOB) during mandibular distraction. The aim of this study was to examine whether 'moulding of the generate', i.e. use of intermaxillary elastics during the active distraction phase is possible to close the mandibular plane angle and open bite.

Three subjects, 13- and 15-year-old males and a 7-year-old female, underwent mandibular linear and angular bilateral distraction osteogenesis with moulding of the generate. Lateral cephalograms were obtained before the introduction of elastics and following distraction, once the activation was stopped and the patients were ready for the consolidation phase. Conventional cephalometric measurements were used to assess possible changes in the mandibular plane angle and incisor position. Three different anchorage systems (dental, orthopaedic, and skeletal) were used for placement of the intermaxillary elastics. Cephalometric examination showed that the mandibular plane angle was decreased during active distraction osteogenesis with the introduction of elastics and angulation of the distraction device. Depending on the type of elastic anchorage system, smaller or greater amounts of extrusion of the incisors were noted.

Moulding of the generate during active distraction can be performed to reduce the mandibular plane angle and open bite. To prevent unwanted dentoalveolar changes from occurring during elastic traction, skeletal rather than dental fixation of the elastics is recommended. Intrusive mechanics may be incorporated into the orthodontic appliances to balance extrusive force by the moulding elastics.

Introduction

Since its introduction (McCarthy *et al.*, 1992), distraction osteogenesis of the craniofacial skeleton has become a widely accepted, safe, and effective means of craniofacial reconstructive surgery. Despite excellent results in general, there are still some uncertainties related to the procedure. Development of an anterior open bite (AOB) during mandibular distraction is an unwanted, yet reported consequence (Molina and Ortiz Monasterio, 1995; Rachmiel *et al.*, 1995; Diner *et al.*, 1997; Williams *et al.*, 1998; Kunz *et al.*, 2000). There are several specific clinical factors, which together or alone may lead to bite opening during mandibular distraction. Patients with an obtuse gonial angle, who have demonstrated backwards (clockwise) growth direction of the mandible, are at risk of bite opening during mandibular distraction if care is not taken (Losken *et al.*, 1995; Kunz *et al.*, 2000). Also, placement of distraction devices and the consequent distraction vector, without consideration being given to the initial mandibular shape, may result in bite opening (Rachmiel *et al.*, 1995; Diner *et al.*, 1997; Samchukov *et al.*, 1999). In addition, masticatory muscles and other soft tissues working on the generate, i.e. newly generated osseus tissue, may direct the mandibular body into a clockwise rotation, clinically seen as an AOB (Losken *et al.*, 1995; Grayson and Santiago, 1999; McCarthy *et al.*, 1999).

Various methods have been proposed and used to control bite opening during mandibular distraction. Hoffmeister and Marcks (1998) introduced the 'floating bone concept', where distraction devices are removed during the consolidation phase in patients who have developed an AOB. The AOB is then closed with intermaxillary elastics. Once bite closing has been achieved, maxillomandibular fixation is placed for 6–8 weeks to allow maturation of the generate. A 'direct manual shaping' method is advocated by Pensler *et al.* (1995) and Kunz *et al.* (2000). Here again, distraction devices are removed once the planned mandibular lengthening has been achieved. The open bite is closed by manual shaping of the callus to achieve optimal occlusion. In this method, either maxillomandibular fixation or rigid external fixation is necessary for bone healing and maturation of the generate.

'Moulding of the generate' is a third option to control an open bite (Grayson and Santiago, 1999; Hanson and Melugin, 1999; McCarthy *et al.*, 1999). This method takes advantage of the presumable mouldability of the generate during its formation. In contrast to the previous methods (Pensler *et al.*, 1995; Hoffmeister and Marcks, 1998; Kunz *et al.*, 2000), moulding is carried out during the activation phase rather than the consolidation phase of distraction osteogenesis. Anterior intermaxillary elastics are introduced concomitantly with angular activation of a multi-planar (multi-dimensional) adjustable distraction device.

The purpose of this study was to examine whether moulding of the generate is possible during active distraction osteogenesis, specifically to evaluate the effect of intermaxillary elastics used for moulding on the position of the mandibular body. This was studied in terms of the changes seen in the mandibular plane angle, incisor extrusion, and/or angulation.

Subjects and methods

The subjects of this study were three patients with severe facial growth anomalies. They were each treated by bilateral distraction osteogenesis to achieve elongation of the mandible. Distraction was performed according to the protocol developed at the Institute of Reconstructive Plastic Surgery, New York University Medical Center (McCarthy, 1994). In each case, external multi-planar distraction devices (Stryker Leibinger, Dallas, Texas) were secured to the mandible with four pins. After a latency period of 7 days, active distraction was performed at the rate of 0.5 mm, twice a day. Once the activation phase was completed, the mandible was kept in fixation for approximately 8 weeks (consolidation phase), at which time maturation of the generate (bone mineralization) was evaluated by a postero-anterior cephalogram and panoramic radiograph. In each case, during active distraction anterior heavy elastics were used to mould the generate, thereby closing an open bite and achieving optimal occlusion.

The intermaxillary elastic traction was achieved in one patient by the engagement of hooks located on orthodontic appliances (dental elastic anchorage system). In the second patient, elastic traction hooks were placed on separately bonded maxillary and mandibular full occlusal coverage splints (orthopaedic elastic anchorage system). In the third patient, traction was achieved by engagement of intermaxillary elastics to hooks located on maxillary bone screws and mandibular symphyseal bone plate (skeletal elastic anchorage system). Intermaxillary elastic traction and the consequent effects of different anchorage systems resulted in different clinical outcomes.

Subject 1. Dental elastic anchorage system

This patient, a male, was born with bilateral temporomandibular joint (TMJ) fusion. Prior to treatment he had multiple mandibular osteotomies, bone grafts, and attempts at TMJ reconstruction. At 15 years of age, he underwent bilateral gap arthroplasty and bilateral transport distraction (Stucki-McCormick, 1997) using an external device. He was distracted a total of 45 mm bilaterally. On the 45th day of distraction, intermaxillary moulding elastics were inserted (Figure 1). The elastics (double 1/4″ heavy) were applied bilaterally in the buccal segments, and anteriorly to hooks on fixed orthodontic appliances containing 0.018 × 0.025 steel archwire. The elastics were worn 24 hours per day for 17 days, followed by stainless steel intermaxillary ligation during 56 days of consolidation (Figure 1). The tracheostomy tube was removed 10 months after the removal of the distraction device.

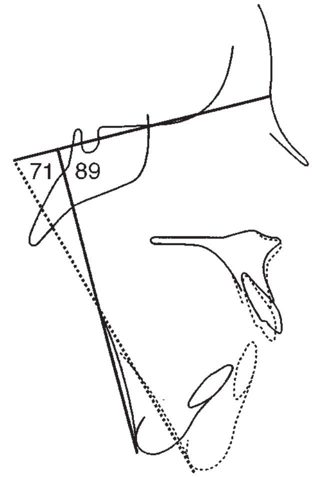

Figure 1 Subject 1, dental elastic anchorage system. With the concomitant introduction of angulation to distraction devices and anterior intermaxillary elastics applied bilaterally to hooks fixed to orthodontic appliances, the mandibular plane angle and open bite were controlled during the activation phase of distraction. Prior to moulding the generate (solid line) the mandibular plane angle was 89 degrees, and following moulding (dashed line), mandibular plane angle decreased by 18 degrees, with considerable extrusion and tipping of the incisors.

Subject 2. Orthopaedic elastic anchorage system

This patient, a female, was born with Treacher Collins syndrome and cleft palate. At 3 years of age she underwent bilateral mandibular distraction, and was decannulated 2 months later. At 6 years of age she underwent bilateral pennant flaps and lateral canthopexies. At 7 years of age re-insertion of the tracheostomy was necessary because of severe sleep apnoea. Consequently, secondary bilateral mandibular distraction was performed. To close the AOB, double bilateral intermaxillary moulding elastics (1/4″ heavy) were applied in a triangular fashion per side (to three hooks, two in the mandible and one in the maxilla) for 24 hours per day starting on day 18 of distraction (Figure 2). The elastics were anchored to hooks embedded in the perimeter of acrylic splints, which were cemented to the occlusal surfaces of the maxillary and mandibular dental arches (Figure 3). The elastics were used 24 hours per day for 3 weeks, and thereafter only when sleeping during the consolidation period. The decision to use acrylic splints for the elastics was based on the patient's mixed dentition stage, which prevented the use of full fixed orthodontic appliances. The total amount of distraction was 34 mm on the right and 36 mm on the left side.

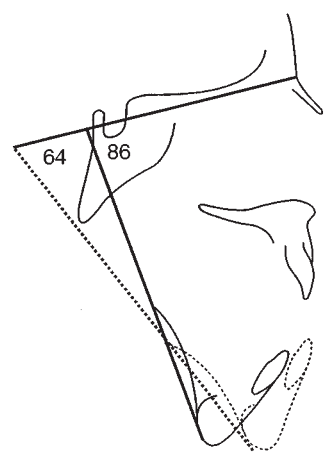

Figure 2 Subject 2, orthopaedic elastic anchorage system. With the concomitant introduction of angulation to distraction devices and anterior intermaxillary elastics applied bilaterally to hooks embedded into the acrylic splints cemented to the maxillary and mandibular dental arches, the mandibular plane angle and open bite were controlled during the activation phase of distraction. Prior to moulding the generate (solid line), the mandibular plane angle was 86 degrees, and following moulding (dashed line), the mandibular plane angle decreased by 22 degrees with limited dentoalveolar changes.

Subject 3. Skeletal elastic anchorage system

This patient, a male, was born with severe micrognathia. He had undergone multiple procedures including bilateral TMJ release, free fibula microvascular reconstruction, and bilateral Silastic TMJ implants. He underwent

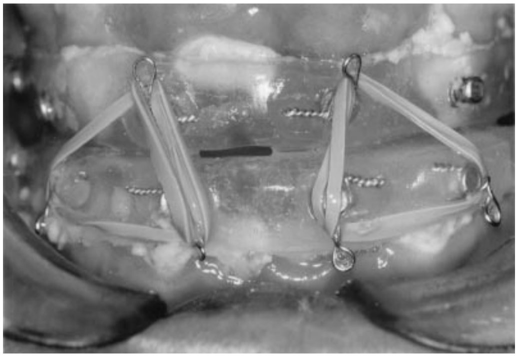

Figure 3 Subject 2, orthopaedic elastic anchorage system. Intermaxillary orthopaedic elastic traction was applied to hooks embedded in the acrylic splints cemented to the maxillary and mandibular dental arches. Except for the anchorage systems for the intermaxillary elastics, they were applied in a similar fashion to subjects 1 and 3.

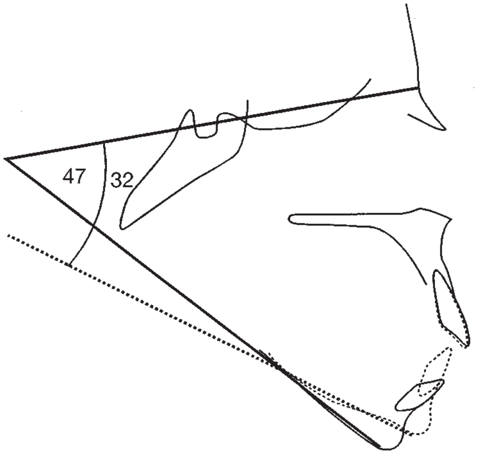

Figure 4 Subject 3, skeletal elastic anchorage system. With the concomitant introduction of angulation to distraction devices and anterior intermaxillary elastics applied bilaterally to the wire hooks fixed to bone screws anchored to the inferior rim of the piriform aperture and the mandibular symphyseal plate, the mandibular plane angle and open bite were controlled during the activation phase of distraction. Prior to moulding the generate (solid line), the mandibular plane angle was 47 degrees, and following moulding (dashed line), the mandibular plane angle decreased by 15 degrees with limited dentoalveolar changes.

three bilateral mandibular distractions, most recently at 13 years of age. Once bite opening was noted on distraction day 24 (Figure 4), moulding elastic therapy was initiated by using two to four full-time 1/4 inch heavy elastics. The elastics were secured to maxillary wire hooks from previously placed screws anchored to the inferior rim of the piriform aperture. Elastics were secured in the mandible to wire hooks attached to a previously placed mandibular symphyseal plate used in the free fibula reconstruction. With the distractor, angle A was changed from 180 to 160 degrees bilaterally on distraction day 34, and again from 160 to 140 degrees bilaterally on distraction day 41. The total amount of distraction was 43 mm bilaterally. The consolidation period lasted for 58 days.

Lateral cephalograms were obtained in all patients before the introduction of moulding elastics and after completion of the activation phase of distraction, i.e. once the activation was stopped and the patients were ready for the consolidation phase. This revealed the mandibular morphological changes which occurred during the period that the intermaxillary elastic traction was used. The following cephalometric measurements were performed. Mandibular plane angle (gonion–menton to sella–nasion): an angle between the mandibular plane and skull base (S–Na). Since distraction devices obscured the cephalometric identification of gonion in most cases, a repeatably identifiable portion of the anterior mandibular lower border and the symphysis was used to establish the mandibular plane. Palatal plane to cranial base: an angle between palatal plane (ANS–PNS) and skull base (S–Na). Upper incisor inclination (upper central incisor axis to ANS–PNS): angle between the long axis of the upper central incisors and palatal plane. Lower incisor inclination (lower central incisor axis to the mandibular plane): angle between the long axis of the lower central incisors and mandibular plane (defined above). The linear measurements were recorded from the upper incisor edge to ANS (UIE–ANS), and lower incisor edge to menton (LIE to Me).

Results

The mandibular plane angle decreased in all patients during active distraction osteogenesis with the introduction of elastics and angulation of the distraction devices. On the other hand, no changes were seen in the inclination of the palatal plane compared with the skull base. Depending on the type of elastic anchorage system (dental, orthopaedic, or skeletal), smaller or greater amounts of extrusion and/or tipping of the incisors were observed. In subject 1, with elastics applied directly to the fixed orthodontic appliances, a significant amount of extrusion (3 mm maxillary, 5 mm mandibular) and tipping (9 degrees maxillary and 12 degrees mandibular) of the incisors was observed, with an 18 degree reduction in the mandibular plane angle. Subject 2, with full coverage acrylic splints for the elastics, showed the greatest amount of mandibular plane angle closure (22 degrees), yet only minor extrusion of the upper and lower incisors (1 mm). Subject 3, with the skeletal elastic anchorage system, showed a 15-degree reduction in the mandibular plane angle and no dental changes (Table 1).

Discussion

This study demonstrates that moulding of the generate during active distraction can be performed to reduce the mandibular plane angle and control an open bite. Similar findings were reported in a study where experimentally produced open bites were closed with heavy coils placed between the maxilla and mandible in rabbits (Yen *et al.*, 2001). It is possible to control distraction vectors (force and direction) taking advantage of the activation possibilities of a multi-planar distraction device. However, since the device to the bone interface is only semi-rigid, the surrounding soft tissues (suprahyoid muscles) may work against bite closing. During active mandibular distraction, intermaxillary elastic traction was considered essential to achieve skeletal change and a precise occlusal outcome.

Compared with other systems for generate moulding (Pensler *et al.*, 1995; Hoffmeister and Marcks, 1998; Kunz *et al.*, 2000) the benefit of this method is the achievement of optimal mandibular position and occlusion during active distraction. No additional procedures are needed once distraction is completed and the patient is ready for the consolidation phase. It is recommended that pre-distraction orthodontic treatment be performed as in the case of orthognathic surgery. In other words, to co-ordinate maxillary and mandibular arch widths and occlusal planes, decompensate incisor angulations, and correct rotations. Pre-distraction orthodontics will often eliminate occlusal interferences during active distraction, which will facilitate achievement of the planned outcome.

The present cephalometric measurements show that, depending on the type of elastic anchorage system (dental, orthopaedic, or skeletal) used for the intermaxillary elastic traction, varying amounts of skeletal and dental changes occur. To prevent unwanted dentoalveolar changes from occurring during elastic use, skeletal elastic anchorage rather than dental anchorage is recommended. However, if orthodontic appliances are used for the intermaxillary moulding elastics, heavy rectangular wires or a bonded occlusal splint are recommended to prevent distortion of the dental arches. In addition, intrusive

Table 1 Changes in the skeletal and dental variables following use of heavy anterior intermaxillary elastic traction concomitant with angulation of bilateral mandibular distraction devices to control mandibular plane angle and open bite.

	Subject 1	Subject 2	Subject 3
Mandibular plane to S–Na (°)	–18	–22	–15
ANS–PNS to S–Na (°)	0	–0.5	+0.5
Upper incisor to ANS–PNS (°)	–9	0	–1
UIE–ANS (mm)	+3	+1	+0.5
Lower incisor to the mandibular plane (°)	–12	+5	–10
LIE–Me (mm)	+5	+1	0

mechanics should be added to balance extrusive forces by the elastics.

Long-term follow-up studies are necessary to confirm stability of skeletal and dental changes that occur during moulding of the generate. It can be speculated, however, that when dentoalveolar changes are kept to a minimum during elastic use, better stability is achieved than if bite closing is (even partially) obtained by extrusion of the incisors. Use of intermaxillary elastic traction during active distraction highlights the importance of collaboration between orthodontist and surgeon. In these endeavours the orthodontist serves the patient and treatment team by delivery of not only pre- and post-distraction orthodontics, but intra-distraction orthodontic management as well. Hanson and Melugin (1999) have stressed the important role of an orthodontist particularly during unilateral mandibular distraction in applying elastics to prevent severe laterognathism. Moreover, this study demonstrates the important role of the orthodontist in applying mechanics for moulding of the generate during active distraction.

Conclusions

The present cephalometric study of three patients who underwent bilateral mandibular distraction showed that:

1. Moulding of the generate during active distraction can be performed to reduce the mandibular plane angle and close or prevent an open bite.
2. A skeletal anchorage system is probably more effective to achieve the desired skeletal change, i.e. closure of the skeletal open bite, than a dental anchorage system.

Furthermore, it can be suggested that to prevent unwanted dentoalveolar changes from occurring during intermaxillary elastic traction, intrusive mechanics in the orthodontic appliance can be added to balance the extrusive forces of intermaxillary moulding elastics. To take advantage of the dynamic state of the generate during active distraction requires that an orthodontist is an active member in the craniofacial team, not only pre- and post-distraction, but also during distraction.

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