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Introduction of the "Rotterdam mandibular distractor" and a biomechanical skull analysis of mandibular midline distraction

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Abstract

The Rotterdam mandibular distractor (RMD) is a slim, rigid, boneborne distractor for use in midline distraction of the mandible. We did a biomechanical study to compare the RMD with the Trans Mandibular Distractor-flex (TMD-flex). This included an anatomical biomechanical study that was conducted on 9 dentate human cadaveric heads using both the RMD and the TMD-flex. In the vertical plane less tipping was measured in the RMD group than in the TMD-flex group. Significantly less skeletal tipping was found in the horizontal plane in the RMD group ($P = 0.021$). There was minimal difference in the intercondylar distance between the groups. As the amount of lateral displacement of the condyle was similar in both groups and there was less rotational movement in the RMD group, the TMD-flex would be expected to increase stress on the temporomandibular joint. As a result of the increased parallel widening in the vertical plane, more basal bone is being created and less relapse is expected using the RMD. The study design involves an in vitro anatomical model and conclusions must be drawn with care. At present clinical studies are under way and results will follow.

Keywords: Mandibular midline distraction; Mandibular symphyseal distraction osteogenesis; Biomechanical analysis; Cadaver; Relapse; Rotterdam mandibular distractor

Introduction

Transverse mandibular deficiencies are seen in patients with congenital deformities such as Nager syndrome, Hypoglossia-hypodactyly syndrome, and 18p syndrome.[1,2] However, most affected patients have developmental deformities of the mandible. These transverse deficiencies can result in (anterior) crowding, unilateral or bilateral crossbite, or other maxillomandibular discrepancies.[3–5] Tooth stripping might be a suitable way to treat minimal crowding. However, in cases with more severe crowding, extraction together with orthodontic treatment, or mandibular midline distraction is indicated.[4,6] The main disadvantages of extraction and orthodontic treatment are the shortened dental arch and the considerable relapse in the post-retention phase.[7]

In mandibular midline distraction the mandible is widened using distraction osteogenesis (DO). A (para)median osteotomy is made, and a distractor attached. Different types are available: toothborne, hybrid (toothborne and boneborne), and boneborne distractors. Important distractor-related aspects of mandibular midline distraction are oral hygiene, the comfort of the patient, and the biomechanical effects of the device.[8,9] To some extent all distractors can

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be troublesome for a patient. Toothborne devices can interfere with speech and eating, whereas hybrid and boneborne devices can be irritating to the lip, or cheek, or both. The most common problems affect the soft tissues, and may include gingivitis, gingival recession, and irritation of the mucosa. Gingivitis and gingival recession are partly the result of the distractor device, which hampers tooth brushing and inhibits oral hygiene. A higher incidence is found in boneborne and hybrid devices as, because of their bulky design, they interfere to a greater extent with brushing teeth.[10–13]

The biomechanical aspects of distractors are important as they can influence the outcome of distraction in the long term, perhaps causing relapse and disorders of the temporomandibular joint (TMJ). The rigidity of a distractor and the vector of the distraction forces mainly define its biomechanical effects, and contribute to the amount of skeletal tipping in all planes. Because toothborne devices apply their vector of force above the centre of resistance they create more vertical skeletal and dental tipping.[14,15] In general, both skeletal and dental tipping are associated with increased relapse of treatment, so therefore a rigid distractor is preferable.[6,9] Boneborne distractors exclude dental tipping completely.

It has been suggested that a rigid distractor would increase the stress on the TMJ and subsequently the risk of disorders of the TMJ.[16] The Trans Mandibular Distractor-flex (TMD-flex, Surgitec, Sint-Denijs-Westrem, Belgium) is an extremely pliable distractor that was specifically designed to reduce the stress on the TMJ itself.[16]

Little research has been reported that quantifies the differences between the different types of boneborne distractors. Boccaccio et al. reported a fine element study on all three distractor designs, and concluded that toothborne devices create a more proportional aperture at dental and distractor levels.[17] However, this proportional widening at dental level does not indicate a proportional widening at the basal bony level, which is important to minimise long-term relapse.

To minimise problems with the soft tissues and improve the biomechanical benefits of boneborne distractors, we developed the 'Rotterdam mandibular distractor' (RMD. KLS Martin, Tuttlingen, Germany), which is a rigid, boneborne distractor with a slim design.

The aim of this study was to compare the RMD with the TMD-flex and evaluate their widening patterns in a biomechanical cadaver model. We expected less skeletal tipping, and a reduction of stress on the TMJs using the RMD.

Material and method

Introduction of the Rotterdam mandibular distractor (RMD)

The RMD is a rigid boneborne distractor (Fig. 1). The distractor consists of a hyrax activation unit with two, 4-holed miniplates attached. The miniplates can be adjusted to fit to the contour of the mandible, and if vertical space is limited they can be shortened. The activation unit is made of a titanium alloy and the miniplates are made of titanium grade II. Two sizes, 10 and 15 mm, are available, depending of the amount of distraction needed. An activation turn of 90° gives 0.25 mm of widening.

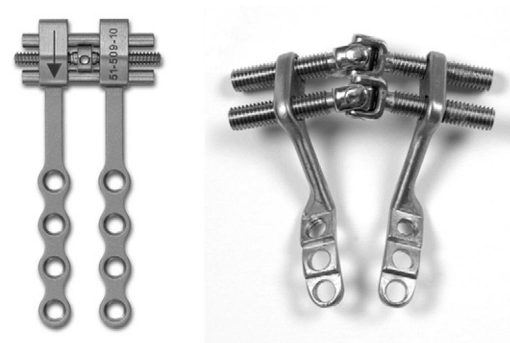

Fig. 1. Rotterdam mandibular distractor (left), and Trans Mandibular Distractor-flex (right).

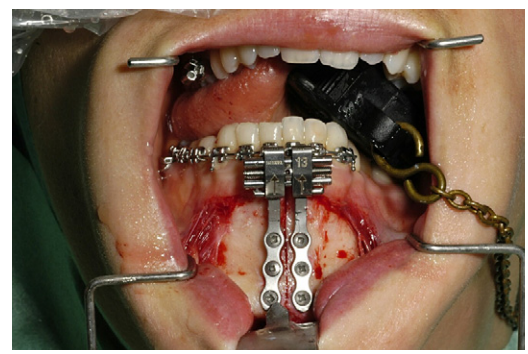

Fig. 2. Rotterdam mandibular distractor in place.

Surgical technique

The operation is done under general anaesthesia. A horizontal incision is made at the junction of the attached gingiva and the unattached mucosa. The mucoperiosteum is retracted to the lower border of the chin. This is followed by a midline osteotomy towards the alveolar process, the alveolar process is left intact at this point. The distractor is adjusted and fixed with 6 or 8 screws depending on the length of the miniplates (Fig. 2). Typically, a 2.0 mm system is used; 7 mm screws are used for the lower holes and 5 mm for the upper holes to avoid root damage. The osteotomy is then completed using an osteotome. To test the distractor in situ it is temporarily activated. After the wound has been rinsed, sutures are used to close the mucoperiosteum.

Biomechanical study

The anatomical, biomechanical study was carried out using 9 dentate human cadavers. First, all cadavers were stripped of their soft tissues, only the temporomandibular joint ligaments

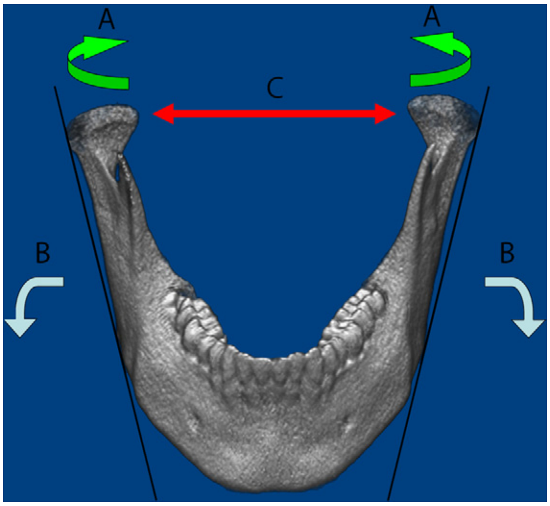

Fig. 3. A: horizontal skeletal tipping, B: vertical skeletal tipping, and C: intercondylar distance.

being left intact. Each skull was fixed on an investigation table using a 4-pin anatomical specimen holder.[18] An osteotomy was made in the midline of the mandible, and one of the two distractors was attached to the mandible. To minimise errors of measurement, and to simulate the natural position of the mandible, it was fixed with a wire and attached to the distractor and a cranially-positioned holder. Attention was taken to prevent contact between the upper and lower dentition.Two different types of distractors were applied to all specimens: the TMD-flex and the RMD. The distractors were gradually activated to 8 mm. During distraction the movement of the hemimandibles was monitored with an optoelectronic system (Optrotrak 3020; Northern Digital Inc, Waterloo, Canada).[18] The system uses active markers that measure the movements of an object with a resolution of greater than 0.02 mm. Two plastic plates were attached to the condyle on both hemimandibles using osteosynthesis screws. Each plate included 3 markers positioned in a triangular configuration. This made it possible to measure intercondyle distance, horizontal and vertical skeletal tipping during distraction (Fig. 3). The system is able to measure angulations with a resolution of 0.05°. To objectify unwanted movements of the skull during the measurements, an additional plate was attached to the frontal bone of the specimen. Measurements were made before, during, and after distraction.

Data are expressed as mean (SD) and results were analysed with the help of the Wilcoxon signed ranks test.

Results

The results are summarised in Table 1. The mean (SD) vertical tipping differed between the TMD-flex (4.45° (SD: 4.67)) and the RMD distractor (2.62° (SD: 1.83)). In the horizontal plane angulations that were found also differed for both distractors, the mean (SD) horizontal tipping was 6.42° (SD: 3.95) for TMD-flex and 2.96° (SD: 2.30) for the RMD. There was a minimal difference in the intercondyle distance, the TMD-flex having an increase of 0.29 (SD: 0.22) mm and the RMD 0.30 (SD: 0.16) mm. The Wilcoxon signed rank test showed that only horizontal tipping differed significantly between the TMD-flex and RMD groups ($P = 0.21$).

Table 1
Mean (SD) horizontal skeletal tipping (°), mean (SD) vertical skeletal tipping (°), and mean (SD) intercondylar distance (mm).

	Transmandibular-flex distractor (SD)	Rotterdam mandibular distractor (SD)
Horizontal skeletal tipping*	6.42 (3.95)	2.96 (2.30)
Vertical skeletal tipping	4.45 (4.67)	2.62 (1.83)
Intercondylar distance	0.29 (0.2)	0.30 (0.16)

* P-value HST = 0.021

Discussion

With the introduction of mandibular midline distraction in the 1990s we became able to widen the mandible surgically. Although there is reasonable consensus among surgeons about the procedure itself, the type of distractor is the subject of debate. The outcome of distraction osteogenesis is influenced by several variables: blood supply to the osteotomy gap, latency period, the rhythm and rate of distraction, the vector of distraction, duration of the consolidation period, and micromotion.[19–21] The first distractors used were toothborne and activated with a hyrax activation unit; later, hybrid and boneborne devices were introduced.[5,6,12,16,22] To optimise oral hygiene, minimise discomfort to the patient, and to get an optimal biomechanical result, it was necessary to adjust the design of the distractor. With the introduction of the RMD we had a slim and rigid boneborne distractor. The size contributes to the patient's comfort during the treatment and makes it easier to maintain adequate oral hygiene. We know of no clinical trials of the RMD, but our first experiences with it are promising, the distractor is well accepted by patients, and we found few lesions of the soft tissues.

The biomechanical effects of a distractor are primarily defined by the vector of the distraction force and the rigidity of the device. To minimise relapse, regeneration of bone is necessary at both basal and alveolar level, and this is obtained with parallel expansion of the hemimandibles.[23] Toothborne devices apply their vector above the centre of resistance and induce less parallel expansion than boneborne distractors. In addition, by applying distraction forces directly to the teeth, toothborne appliances cause dental tipping and because of the continuous high forces on the teeth, roots are likely to resorb.[24] The presence and increased risk of dental and skeletal tipping and related relapse, combined with the risk of root resorption are, in our opinion, reasons why toothborne and hybrid appliances are less recommended.

Within the boneborne distractor group different appliances are available, each with their own specific design. Mommaerts introduced the Trans Mandibular Distractor-flex and later the 'transmandibular distractor-flex' (TMD-flex), both of which are designed with limited rigidity, particularly in the horizontal plane to minimise the increase in intercondylar distance, and so minimise the danger of dysfunction of the TMJ.[16,22] The results of the present study indicate a tendency towards less vertical tipping in the RMD than the TMD-flex group, but not significantly so being 2.62° (SD: 1.83) and 4.45° (SD: 4.67), respectively, implying more rigidity in the vertical plane for the RMD. Further, there was significantly less horizontal tipping in the RMD group than the TMD-flex group, 2.96° (SD: 2.30) compared with 6.42° (SD: 3.95) ($P = 0.021$). For the RMD this is in line with the 0.34° exorotational movement/mm distraction proposed by Samchukov.[19] Although the RMD has a rigid design and should theoretically create more lateral displacement of the condyles than the TMD-flex, we found no difference in the amount of lateral displacement between high-rigidity and low-rigidity distractors (0.30 (SD: 0.16) mm compared with 0.29 (SD: 0.2) mm). Harper reported that damage to the cartilage seen in mandibular midline distraction is mainly the result of exorotational forces.[25] Because the amount of lateral displacement in both groups is similar, and there is additional rotational movement in the TMD-flex group, the RMD induces less stress to the condyles and so less TMJ dysfunction is expected which is in contrast to the results of Mommaerts.[16] In addition, more basal bone is created as a result of the more parallel widening in the vertical plane and therefore less relapse is expected using the RMD.

The study design that we used is an in vitro model and provides, at best, an approximation of what will happen in vivo, so our study has limitations, and conclusions must be drawn with caution. A limitation of the study is the paucity of soft tissue in our model, specifically of the masticatory muscles as these create forces on the mandible, and so might influence the vector of the distraction. Another influencing factor could have been the position of the fixation wire, because it is attached to the distractor and so can influence the position of the mandible. Despite its limitations, we think that our model adds valuable information about the biomechanical effects on the two types of boneborne distractors.

References

1. Kessler P, Wiltfang J, Merten HA, Neukam FW. Distraction osteogenesis of the mandible in craniofacial abnormalities. *Mund Kiefer Gesichtschir* 2000;**4**:178–82 [in German].
2. Kita H, Kochi S, Yamada A, et al. Mandibular widening by distraction osteogenesis in the treatment of a constricted mandible and telescopic bite. *Cleft Palate Craniofac J* 2004;**41**:664–73.
3. King JW, Wallace JC. Unilateral Brodie bite treated with distraction osteogenesis. *Am J Orthod Dentofacial Orthop* 2004;**125**:500–9.
4. Proffit WR, White RP, Sarver DM. *Contemporary treatment of dentofacial deformity*. St. Louis: Mosby; 2003.
5. Guerrero CA, Bell WH, Contasti GI, Rodriguez AM. Mandibular widening by intraoral distraction osteogenesis. *Br J Oral Maxillofac Surg* 1997;**35**:383–92.
6. Conley R, Legan H. Mandibular symphyseal distraction osteogenesis: diagnosis and treatment planning considerations. *Angle Orthod* 2003;**73**:3–11.
7. Little RM. Stability and relapse of dental arch alignment. *Br J Orthod* 1990;**17**:235–41.
8. Ilizarov GA. Clinical application of the tension-stress effect for limb lengthening. *Clin Orthop Relat Res* 1990;(250):8–26.
9. Koudstaal MJ, Wolvius EB, Schulten AJ, Hop WC, van der Wal KG. Stability, tipping and relapse of bone-borne versus tooth-borne surgically assisted rapid maxillary expansion; a prospective randomized patient trial. *Int J Oral Maxillofac Surg* 2009;**38**(April (4)):308–15.
10. Alkan A, Ozer M, Bas B, et al. Mandibular symphyseal distraction osteogenesis: review of three techniques. *Int J Oral Maxillofac Surg* 2007;**36**:111–7.
11. Mommaerts MY, Spaey YJ, Soares Correia PE, Swennen GR. Morbidity related to transmandibular distraction osteogenesis for patients with developmental deformities. *J Craniomaxillofac Surg* 2008;**36**:192–7.
12. Uckan S, Guler N, Arman A, Mutlu N. Mandibular midline distraction using a simple device. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006;**101**:711–7.
13. Gunbay T, Akay MC, Aras A, Gomel M. Effects of transmandibular symphyseal distraction on teeth, bone, and temporomandibular joint. *J Oral Maxillofac Surg* 2009;**67**:2254–65.
14. Chung YW, Tae KC. Dental stability and radiographic healing patterns after mandibular symphysis widening with distraction osteogenesis. *Eur J Orthod* 2007;**29**:256–62.
15. Seeberger R, Kater W, Davids R, et al. Changes in the mandibular and dento-alveolar structures by the use of tooth borne mandibular symphyseal distraction devices. *J Craniomaxillofac Surg* 2011;**39**:177–81.
16. Mommaerts MY, Polsbroek R, Santler G, Correia PE, Abeloos JV, Ali N. Anterior transmandibular osteodistraction: clinical and model observations. *J Craniomaxillofac Surg* 2005;**33**:318–25.
17. Boccaccio A, Lamberti L, Pappalettere C, Cozzani M, Siciliani G. Comparison of different orthodontic devices for mandibular symphyseal distraction osteogenesis: a finite element study. *Am J Orthod Dentofacial Orthop* 2008;**134**:260–9.
18. Koudstaal MJ, Smeets JB, Kleinrensink GJ, Schulten AJ, van der Wal KG. Relapse and stability of surgically assisted rapid maxillary expansion: an anatomic biomechanical study. *J Oral Maxillofac Surg* 2009;**67**:10–4.
19. Samchukov ML, Cope JB, Harper RP, Ross JD. Biomechanical considerations of mandibular lengthening and widening by gradual distraction using a computer model. *J Oral Maxillofac Surg* 1998;**56**:51–9.
20. Bell WH, Gonzalez M, Samchukov ML, Guerrero CA. Intraoral widening and lengthening of the mandible in baboons by distraction osteogenesis. *J Oral Maxillofac Surg* 1999;**57**:548–63.
21. Djasim UM, Wolvius EB, Bos JA, van Neck HW, van der Wal KG. Continuous versus discontinuous distraction: evaluation of bone regenerate following various rhythms of distraction. *J Oral Maxillofac Surg* 2009;**67**:818–26.
22. Mommaerts MY. Bone anchored intraoral device for transmandibular distraction. *Br J Oral Maxillofac Surg* 2001;**39**:8–12.
23. Raoul G, Wojcik T, Ferri J. Outcome of mandibular symphyseal distraction osteogenesis with bone-borne devices. *J Craniofac Surg* 2009;**20**:488–93.
24. Weltman B, Vig KW, Fields HW, Shanker S, Kaizar EE. Root resorption associated with orthodontic tooth movement: a systematic review. *Am J Orthod Dentofacial Orthop* 2010;**137**:462–76, discussion 12A.
25. Harper RP, Bell WH, Hinton RJ, Browne R, Cherkashin AM, Samchukov ML. Reactive changes in the temporomandibular joint after mandibular midline osteodistraction. *Br J Oral Maxillofac Surg* 1997;**35**:20–5.