Introduction of the “Rotterdam Mandibular Distractor” and a biomechanical skull analysis of Mandibular Midline Distraction.

J.P. de Gijt, K.G.H. van der Wal, G.J. Kleinrensink, J.B. Smeets, M.J. Koudstaal, Introduction of the Rotterdam Mandibular Distractor, Mandibular Midline Distraction and a biomechanical skull analysis of mandibular midline distraction, British journal of oral and maxillofacial surgery, 2012 Sep;50(6):519-22

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.

Introduction

Transverse mandibular deficiencies are seen in patients with congenital deformities such as Nager syndrome, Hypoglossia-hypodactylia 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 maxillo-mandibular transverse discrepancies.[3-5] Tooth stipping 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 therapy 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 is attached. Different types of are available: toothborne, hybrid (a combination of a toothborne and boneborne) and bone-borne distractors. Important distractor related aspects of MMD are oral hygiene, the comfort of the patient, and the biomechanical effects of a device. To some extent all distractors can 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 tssues, 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, interfere to a greater extent with brushing teeth.[10-13]

The biomechanical aspects of distractors are important as they can influence the outcome of the distraction in the long term, perhaps causing relapse and disorder of the temporomandibular joint disorders (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, 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 increase the risk of disorders of the TMJ.[16] The Trans Mandibular Distractor-Flex in (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. Bocaccio et al. conducted a fine element study on all three distractor designs, and concluded that toothborne devices create a more proportional apperture at dental and distractor level.[17] However, this proportional widening at dental level, does not indicate a proportional widening at the basal bone level, which is important to minimise long-term relapse.

To minimize problems with soft tissue and improve the biomechanical benefits of bone-borne distractors we developed the 'Rotterdam Mandibular Distractor' (RMD. KLS Martin, Tuttlingen, Germany), a rigid bone-borne 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 and dental tipping, and a reduction of stress on the TMJs using the RMD.

MATERIALS & METHODS

Introduction of the Rotterdam Mandibular Distractor (RMD)

The RMD is a rigid bone-borne distractor, see figure 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 degrees gives 0.25 mm. of widening.

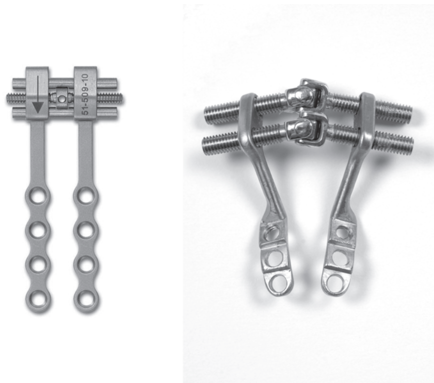

Figure 1. Left: Rotterdam Mandibular Distractor (RMD), Right: Trans Mandibular Distractor-Flex (TMD-Flex).

Surgical technique

The operation is done under general anaesthesia. A horizontal incision is made at the junction of the attached gingival and the non-attached 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, see figure 2. Typically, a 2. 0mm 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.

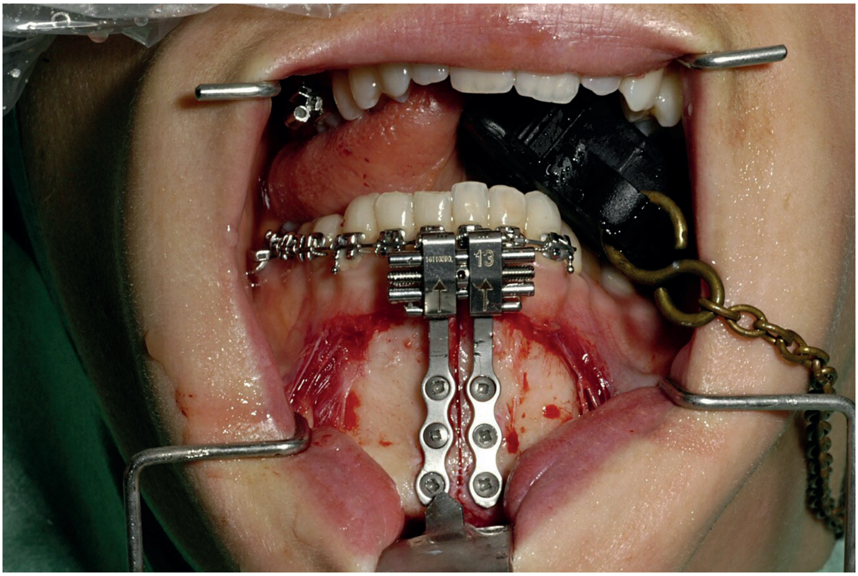

Figure 2. The Rotterdam Mandibular Distractor in situ.

Biomechanical study

The anatomical, biomechanical study was carried out using 9 dentate human cadaver specimens. First, all cadavers were stripped of their soft tissues, only the temporomandibular joint ligaments being left intact. Each skull was fixed on an investigation table using a 4-pin anatomic specimen holder, see figure 3.[18] An osteotomy of the mandible in the midline was made 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 on 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 hemi-mandibles. Each plate includes 3 markers positioned in a triangular configuration. This made it possible to measure intercondyle distance, horizontal and vertical skeletal tipping during distraction. 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 performed before, during and after distraction.

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

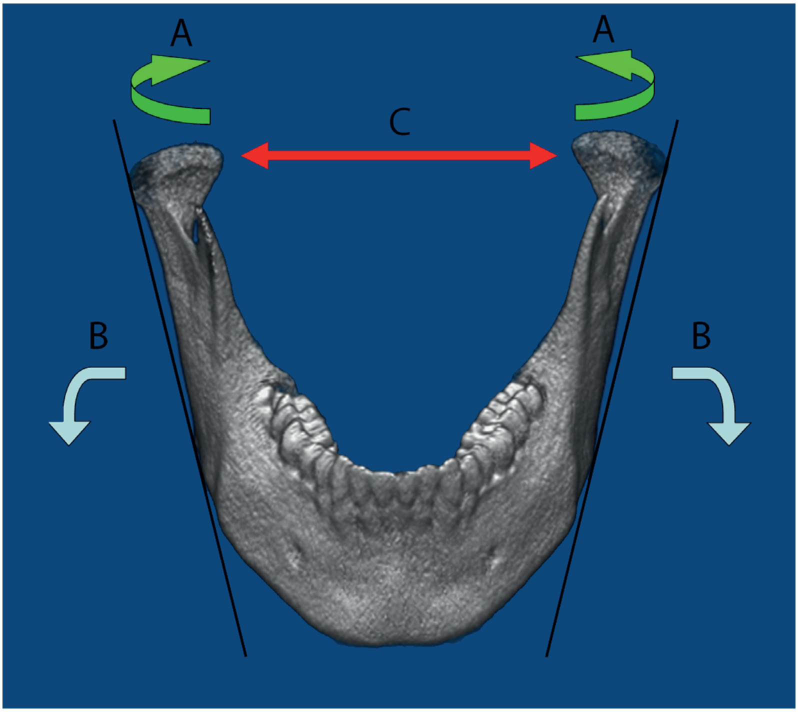

Figure 3. A. Horizontal skeletal tipping; B. Vertical skeletal tipping; C. Intercondyle distance.

RESULTS

The results are summarized in table 1. The mean 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

In the horizontal plane angulations that were found also differed TMD-flex and 2.96° (SD: 2.30) for the RMD. There was a minimal difference in the intercondyle distance, the TMDflex 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. Results, MHT: mean horizontal skeletal tipping; MVT: mean vertical skeletal tipping; ICD: mean intercondyle distance, *: $P < 0.05$.

	MHT*	MVT	ICD
TMD-Flex	6.42°	4.45°	0,29mm.
RMD	2,96°	2,62°	0,30mm.

DISCUSSION

With the introduction of Mandibular Midline Distraction (MMD) 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 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 bone-borne devices were introduced.(5, 6, 12, 16, 22) To optimize oral hygiene, minimise patient discomfort and to get an optimal biomechanical result of the therapy, it was necessary to adjust the distractor design. With the introduction of the Rotterdam Mandibular Distractor we had a slim and rigid bone-borne 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 a less parallel expansion compared to boneborne distractors. In addition, by applying distraction forces directly to the teeth, toothborne appliances create 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 bone-borne distractor group different appliances are available, each with their own specific design. Mommaerts et al. introduced the 'transmandibular distractor' (TMD) 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 of intercondyle distance, and so minimise 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 significant 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) versus 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 et al..[19] Although the RMD has a rigid design and, theoretically create more lateral displacement of the condyles than the TMD-flex, we found no difference in amount of lateral displacement between high-rigidity and low-rigidity distractors, 0.30 mm (SD: 0.16) compared with 0.29mm (SD: 0.2)). Harper et al. 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 observed in the TMD-flex group, the RMD induces less stress to the condyles and thus less TMJ dysfunction is expected which is in contrast to the results of Mommaerts et al..[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 a RMD.

The study design that we used is an in vitro model and provides, at best, an approximation of what will happen in vivo situation, 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, as 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.

LITERATURE

1. Kessler P, Wiltfang J, Merten HA, Neukam FW. [Distraction osteogenesis of the mandible in craniofacial abnormalities]. Mund Kiefer Gesichtschir. 2000 May;4(3):178-82.
2. Kita H, Kochi S, Yamada A, Imai Y, Konno N, Saitou C, et al. Mandibular widening by distraction osteogenesis in the treatment of a constricted mandible and telescopic bite. Cleft Palate Craniofac J. 2004 Nov;41(6):664-73.
3. King JW, Wallace JC. Unilateral Brodie bite treated with distraction osteogenesis. Am J Orthod Dentofacial Orthop. 2004 Apr;125(4):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. The British journal of oral & maxillofacial surgery. 1997 Dec;35(6):383-92.
6. Conley R, Legan H. Mandibular symphyseal distraction osteogenesis: diagnosis and treatment planning considerations. The Angle orthodontist. 2003 Feb;73(1):3-11.
7. Little RM. Stability and relapse of dental arch alignment. British journal of orthodontics. 1990 Aug;17(3):235-41.
8. Ilizarov GA. Clinical application of the tension-stress effect for limb lengthening. Clin Orthop Relat Res. 1990 Jan(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 Apr;38(4):308-15.
10. Alkan A, Ozer M, Bas B, Bayram M, Celebi N, Inal S, et al. Mandibular symphyseal distraction osteogenesis: review of three techniques. Int J Oral Maxillofac Surg. 2007 Feb;36(2):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 Jun;36(4):192-7.
12. Uckan S, Guler N, Arman A, Mutlu N. Mandibular midline distraction using a simple device. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2006 Jun;101(6):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 Oct;67(10):2254-65.
14. Chung YW, Tae KC. Dental stability and radiographic healing patterns after mandibular symphysis widening with distraction osteogenesis. European journal of orthodontics. 2007 Jun;29(3):256-62.
15. Seeberger R, Kater W, Davids R, Thiele OC, Edelmann B, Hofele C, et al. Changes in the mandibular and dento-alveolar structures by the use of tooth borne mandibular symphyseal distraction devices. J Craniomaxillofac Surg. 2011 Apr;39(3):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 Oct;33(5):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 Aug;134(2):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 Jan;67(1):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 Jan;56(1):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 May;57(5):548-62; discussion 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 Apr;67(4):818-26.
22. Mommaerts MY. Bone anchored intraoral device for transmandibular distraction. The British journal of oral & maxillofacial surgery. 2001 Feb;39(1):8-12.
23. Raoul G, Wojcik T, Ferri J. Outcome of mandibular symphyseal distraction osteogenesis with bone-borne devices. The Journal of craniofacial surgery. 2009 Mar;20(2):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 Apr;137(4):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. The British journal of oral & maxillofacial surgery. 1997 Feb;35(1):20-5