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Anterior transmandibular osteodistraction: clinical and model observations

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SUMMARY. Introduction: **The aim of this paper was to study the effect of transmandibular distraction on the periodontal and dental structures, and the initial movements of the mandibular halves, when using an axial plane non-rigid bone-borne distractor (TMD™).** Material and methods: **Fourteen patients undergoing bimaxillary transverse osteodistraction had their six lower anterior teeth assessed for mobility, sensitivity, and pocket depth. Recordings were made pre-operatively, post-distraction, post-consolidation and at 1-year follow-up. Selected landmarks on pre-operative and post-consolidation models were also digitised in three dimensions to study individual tooth movements, and positional changes of the mandibular halves.** Results: **Pockets depths around the incisor teeth increased during the consolidation period (probably due to reduced oral hygiene), but returned to normal by the 1-year post-operative consultation. Tooth mobility increased temporarily in the active phase (central incisors, lateral incisors) and in the consolidation phase (lateral incisors, canine teeth). Sensitivity to cold was temporarily lost in the incisor teeth, probably as a result of 'apical contusion'. One central incisor was inadvertently apically osteotomized and needed root canal treatment. The angle between the mandibular halves closed by 9.4°.** Conclusion: **Periodontal and dental morbidity is transient and limited to the distraction and consolidation period, as long as the tooth apices are avoided when the osteotomy is performed. A step-design osteotomy may be preferable when the central incisor apices are close to each other. The transmandibular distractor (TMD) allows for rotation at the temporomandibular joints.** **© 2005 European Association for Cranio-Maxillofacial Surgery**

Keywords: **osteogenesis; distraction; mandible; chin**

INTRODUCTION

Anterior transmandibular osteodistraction is an alternative to dental extractions, interproximal tooth mass reduction, or orthodontic compensation in cases of severe anterior crowding in the mandible due to a narrow anterior and middle apical area (*Guerrero* et al., 1997; *Weil* et al., 1997; *Mommaerts* et al., 2004). Bimaxillary transverse osteodistraction is indicated when massive anterior crowding is present in both jaws and clearly due to transverse skeletal hypoplasia which is reflected in wide lateral vestibula (*Mommaerts* et al., 2004). The effect of an interdental midline osteotomy on the neighbouring dental and periodontal structures, and the effect of transverse osteodistraction on the position of the incisors and also of the condyles are of concern. These issues probably explain why surgeons and orthodontists do not universally accept this treatment option. Computer-aided-design analysis (*Samchukov* et al., 1998), animal experiments (*Bell* et al., 1997, 1999; *Harper* et al., 1997; *Hollis* et al., 1998) and clinical studies (*Guerrero* et al., 1997; *Weil* et al., 1997; *Kewitt* and *Van Sickels*, 1999; *Del Santo* et al., 2000; *Braun* et al., 2002) have already examined these effects and the potential complications. Tooth-borne osteodistraction is known to cause a disproportionately larger gap at the dentoalveolar level than at the mandibular base (*Bell* et al., 1997). As the distraction force is applied above the centre of resistance of the mandibular halves and since fixation is not rigid, rotation in the frontal plane can result (*Del Santo* et al., 2000). In addition, expansion of alveolar bone alone (i.e. not supported by basal bone) may be unstable and represent a risk of relapse (*Herberger*, 1981). Moreover, teeth can be moved out of the supporting alveolar bone (*Guerrero* et al., 1997; *Hollis* et al., 1998). In contrast, bone-borne transmandibular osteodistractors do not suffer from these disadvantages.

However, rigid bone-borne and tooth-borne distractors can also induce condylar translation in the axial plane (*Braun* et al., 2002).

This single-centre, independent-investigator, prospective, cohort study aims to evaluate the short-term effects of transmandibular osteodistraction (using a bone-borne, axial plane, non-rigid device) on the position of the mandibular halves including the condyles, and the short- and medium-term effects on the involved dental and periodontal structures.

MATERIAL AND METHODS

Patients

The study group comprised 14 consecutive patients (four males and eight females) operated on at the General Hospital St. Jan, Brugge, by two surgeons (MM, JA), except for one patient. Two patients were subsequently excluded (one male, one female) due to incomplete records. The mean age of the remaining 12 patients was 19 years and 11 months at the time of surgery (range 12 years 2 months to 35 years 2 months). All patients were clinically assessed and diagnosed by the referring orthodontists and receiving surgeon as needing transmandibular osteodistraction. The decision was based primarily on indicators such as anterior crowding, transverse hypoplasia of the anterior mandibular segment, and unaesthetic large buccal corridors. All patients had acceptable oral hygiene with no significant pre-existing bone loss or peri-apical pathology. All patients underwent bimaxillary transverse osteodistraction with TPD™ and TMD™ devices (*Mommaerts*, 1999, 2001; *Mommaerts* et al., 2003; Surgi-Tec NV, Brugge, Belgium). Both are bone-borne distractors specifically designed to widen the maxilla (TPD – anteriorly, parallel, posteriorly), and the mandible (TMD – anteriorly). The transpalatal distractor (TPD) comprises two abutment plates, fixed with osteosynthesis screws bilaterally on the palatal shelves, and telescoping distraction modules of different sizes. The transmandibular distractor is a single component with flexible distractor rods, allowing for rotational adaptation in the axial plane.

The average interval between surgery and the end of active osteodistraction was 26.3 days (SD 8.8). The average consolidation period (interval between end of distraction and device removal) was 71.7 days (SD 18.8).

Osteotomy technique

A small round bur was used to mark a vertical dotted line in the anterior cortical bone between the roots of the central incisors, extending to the lower border of the mandible. Guided by the markings a complete vertical osteotomy, extending from the inferior mandibular border to the apical area, was performed using a reciprocating saw. The crestal osteotomy was performed using a small Lindemann bur for the labial cortex followed by small osteotomes for the interdental bone. Fracture of the lingual cortex at the crestal level was achieved by insertion and manipulation of a 1 cm wide osteotome into the osteotomy site at the inferior border of the mandible. This osteotomy technique is similar to that described by *Weil* et al. (1997) and *Guerrero* et al. (1997). One notable difference was limitation of the width of the labial sulcus incision and subsequent subperiosteal dissection to the area between the mentalis muscles, which were not transsected (*Mommaerts*, 2001). The transmandibular distractor was positioned temporarily with two or three screws prior to mobilization of the segments, and then definitively fixed with six screws, three on either side (Fig. 1).

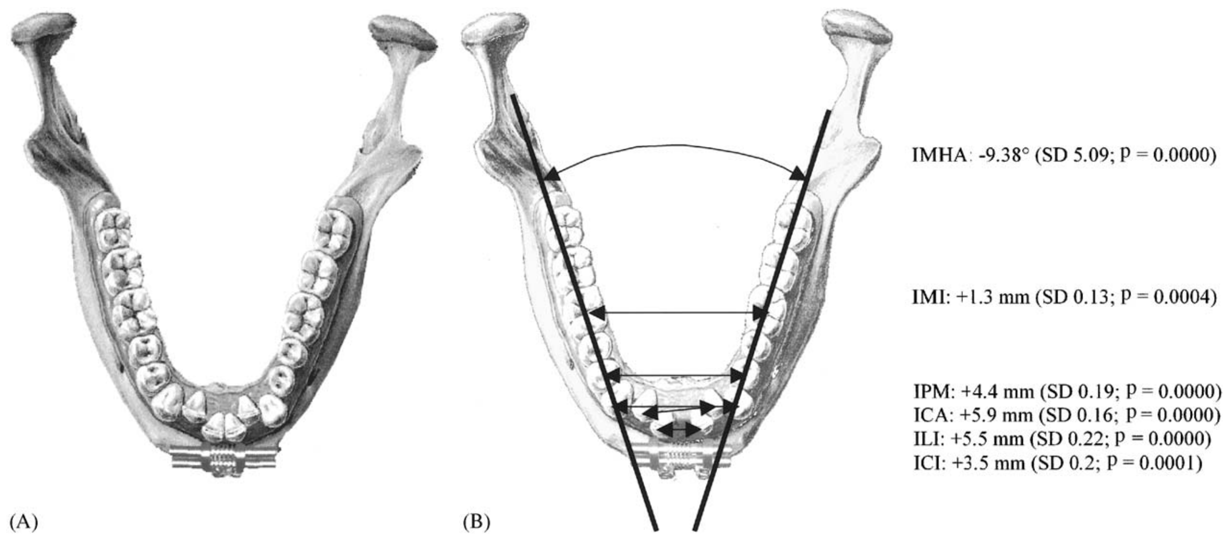

Figure 1 – In this series, the transmandibular distractor (TMD) was fixed to the symphysis with one bicortical and two monocortical screws on either side of a vertical midline osteotomy. Both distractor rods contain a central helicoidal segment that allows for rotational adaptation of the mandibular condyles. (A) Mean pre-distraction situation. The 3D reference plane is constructed with O-point in the middle of the central fissure of 34, and the y-axis is directed from *fossa* 36 to *fossa* 46. The Z-axis is constructed perpendicularly to the x–y axis plane and is directing cephalad. (B) Mean post-consolidation situation and mean differences. Changes in distances and angles along the x-axis between the preoperative and post-consolidation conditions, as measured on plaster models (for abbreviations see Table 1). t-test for paired differences. $n = 12$.

Distraction policy

A 7-day latency period was followed by activation of the distractor. The rate and rhythm of distraction was 0.5 mm/day by one activation only. Removal of the distractors was generally after a 2-month consolidation period, and orthodontic fixed appliances were installed following this. An occlusal radiograph and ultrasound investigation were used to assess the ossification state of the callus, and led to the postponement of distractor removal by 1 month in one patient (*Mommaerts* et al., 2003).

Data collection

Records and data were prospectively gathered by health care professionals working in the department and, after completion, analysed by an independent investigator (RP). Alginate impressions were taken at the time of distractor placement and at the end of the consolidation phase. Models made at a later stage were considered to be of no value because of ongoing orthodontic treatment. Selected landmarks on the plaster models were captured with a Polhemus 3-D digitizer and analysed by the 3-D COSMOS software (*Santler*, 2000). Using this equipment the amount of osteodistraction in the canine/premolar/molar regions was calculated, and the spatial movement of the canines, incisors, and the mandibular halves/condyles during the activation phase analysed. Primary and secondary parameters are listed in Table 1. An x–y reference plane was constructed by the fissures on the dental crowns: landmarks *fossa* 36, *fossa* 46 and *fossa* 34; the y-axis direction from *fossa* 36 to *fossa* 46, the x-axis was made in the sagittal plane, with 0-point at *fossa* 34 and directed anteriorly; the z-axis was constructed perpendicularly to the x–y axis plane and directed cephalad (Fig. 1).

Cold-sensitivity and pocket depths were measured in the anterior region pre-operatively, at the start of the activation, at the end of the consolidation phase, and 1 year post-operatively. Periodontal examination included assessment of tooth mobility (Classes I–III; *Lindhe*, 1983) and pocket depth measurement in millimetres around the six front teeth with a standard periodontal probe (mesiofacial, facial, distofacial, mesiolingual, lingual, distolingual sides). The anterior and posterior mandibular gingival margins were also examined for recession. All patients had periapical and occlusal radiographs of the mandibular anterior teeth before surgery, at the end of the activation and of consolidation periods. Tooth mobility was examined pre-operatively, at the start of the activation and the end of the consolidation phase. 1-year post-operatively mobility was not tested as orthodontic devices splinted the teeth. Tooth sensitivity as an indicator of tooth vitality was assessed by the response to a cold stimulus (Miracold Plus, Hager & Werken GmbH, Duisburg, Germany). Discoloration (clinical feature) and apical lesion (radiological feature) were major criteria for loss of vitality. Ultrasound investigations of the bone were performed at the end of the active and consolidation phases.

Statistical methods

All data was transferred to StatTool 2002 software (Department of Gynaecology and Obstetrics, Chinese University of Hong Kong, free webware) for the descriptive statistics and t-tests for paired differences in small samples (*Siegal* and *Castellan*, 1988). A significance level of $p < 0.05$ was used.

Intraobserver reliability for the model study was calculated using the Intraclass Correlation Test (*Portney* and *Watkins*, 1993) in 12 duplicated models (complete sample) with repeated landmark

Table 1 – Primary (anatomical landmarks) and secondary parameters (distances, angles) used in the model study

	Definitions
Primary parameters	
Fossa 36	Deepest point of the central fossa of the mandibular left first molar
Fossa 34	Deepest point of the distal fossa of the mandibular left first premolar
33	Cuspid point of the mandibular left canine
32	Incisal midpoint of the mandibular left lateral incisor
31	Incisal midpoint of the mandibular left central incisor
41	Incisal midpoint of the mandibular right central incisor
42	Incisal midpoint of the mandibular right lateral incisor
43	Cuspid point of the mandibular right canine
Fossa 44	Deepest point of the distal fossa of the mandibular right first premolar
Fossa 46	Deepest point of the central fossa of the mandibular right first molar
Secondary parameters (*all in x–y plane*)	
ICI	Inter-central incisor distance: distance between 31 and 41
ILI	Inter-lateral incisor distance: distance between 32 and 42
ICA	Inter-canine distance: distance between 33 and 43
IPM	Inter-premolar distance: distance between 34 and 44
IMI	Inter-molar distance: distance between 36 and 46
IMHA	Inter-mandibular halve angle: angle between the line 34–36 and the line 44–46

identification and measurements. The Individual Model 2 Coefficients for the secondary parameters are tabulated in Table 2. The difference between the two ratings was insignificant. The results show high concordance, and consequently, intraobserver reliability was judged to be high.

RESULTS

The result of changes in the transverse dimension between the pre-operative and post-consolidation state are depicted in Figure 1. The average increase in distance between the canine teeth (5.9 mm) and lateral incisors (5.5 mm) was larger than that between the central incisors (3.5 mm). Since transverse movements of the premolar and molar teeth were not expected, the increase in interpremolar distance (IPM) and intermolar distance (IMI) reflect the movement of the mandibular halves during distraction. The average increase in IPM (4.4 mm) being larger than the one in IMI (1.3 mm) indicates a rotational movement of the mandibular halves with a posteriorly located point of rotation. This is confirmed by the decrease of the angle between the mandibular halves (IMHA) by 9.4 degrees on average.

The results of tooth movements in the sagittal direction are tabulated in Table 3. On average there was a small but significant anterior movement of the incisors no. 32, 31 and 41.

In the vertical direction, only tooth 33 moved upwards by 0.2 mm on average (SD 0.03; $p = 0.0433$), which was clinically insignificant.

The mean pocket measurements of the mandibular front-teeth are depicted in Figure 2. Pocket depth increased mainly during the consolidation period, and at the central incisors, to return to normal values at the consultation 1 year post-operatively. The mean values of the mesiofacial and mesiolingual pockets of the central incisors, lateral to the median osteotomy, were 2.4 mm (SD 0.54) pre-operatively, 3 mm (SD 1.48) at the end of the active distraction phase, 3 mm (SD 1.04) at the end of the consolidation period, and 2.6 mm (SD 0.86) after 1 year. The pre-operative value was significantly different (one-way ANOVA) from

Table 3 – Changes in position of the front teeth in the *x*-direction. *t*-test for paired differences, $n = 12$. Non-significant movements (NS) not tabulated

Primary parameter	Mean difference between the predistraction and postconsolidation situations (mm)	SD	*p*
33			NS
32	1.1	0.14	0.0139
31	1.3	0.1	0.001
41	1.5	0.17	0.0009
42			NS
43			NS

Table 2 – Intraclass coefficients* (Model 2, individual) for the secondary parameters

Parameter	Pre-operative models		Post-operative models	
	Intraclass correlation coefficient	*F*	Intraclass correlation coefficient	*F*
ICI	0.9215	0.0499	0.9956	2.4561
ILI	0.9844	3.0155	0.9974	0.0443
ICA	0.9920	1.9310	0.9945	0.8103
IPM	0.9956	2.1153	0.9971	0.0000
IMI	0.9985	0.3117	0.9992	3.3432
IMHA	0.9919	1.4414	0.9947	3.9616

*_Intraclass correlations_ are correlations used as reliability coefficients among evaluations of items that are deemed to be in the same category or class.

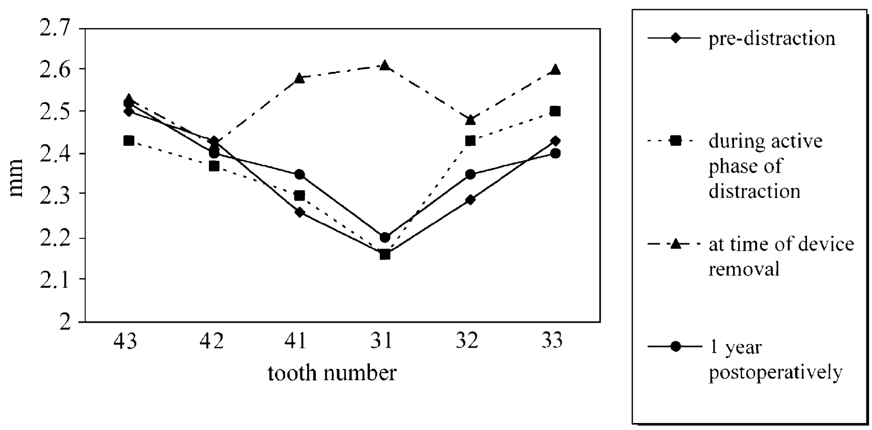

Figure 2 – Mean pocket depths (mean of 6 surfaces per tooth) of the mandibular front teeth.

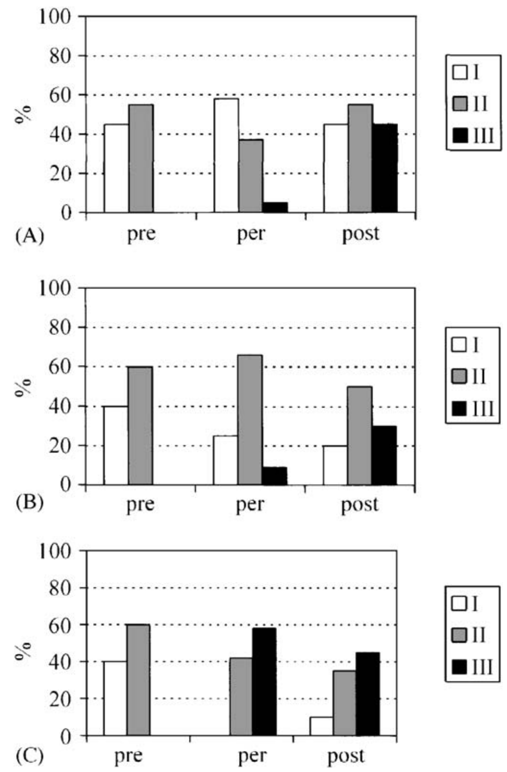

Figure 3 – Mobility scores. Tooth mobility was examined preoperatively (pre), at the start of the activation (per) and the end of the consolidation phase (post). (A) mean of the canines, (B) mean of the lateral incisors. (C) mean of the central incisors. I. horizontal mobility of 0.2–1 mm; II: horizontal mobility of 1–2 mm; III: horizontal mobility of 2 mm and/or more, or vertical mobility.

the value after active distraction ($p = 0.0071$), and the value at the end of the consolidation period ($p = 0.0002$).

Mean mobility scores for the canines, lateral and central incisors are depicted in Figure 3. Overall mobility of the canine and lateral incisor teeth was greater after consolidation than after active distraction. In contrast, the mean mobility of the central incisors increased dramatically during the active phase of distraction.

The results of the cold testing are depicted in Figure 4. Twice as many central incisors failed to respond to a cold stimulus after consolidation than after active distraction. However, sensitivity did eventually return in all but one of these teeth in the months following distractor removal: One central incisor showed discolouration by the end of the activation period, and on radiographic imaging showed an apical section (Fig. 5).

DISCUSSION

For the indication for transverse mandibular distraction as performed in this series, we refer the reader to the concept paper (*Mommaerts* et al., 2004) and a clinical case presentation (*Mommaerts* and *vande Vannet*, 2004). An osteodistraction alternative to treat anterior mandibular crowding is anterior rotation of the mandibular canine-to-canine segment (*Triaca* et al., 2001). However, this concept does

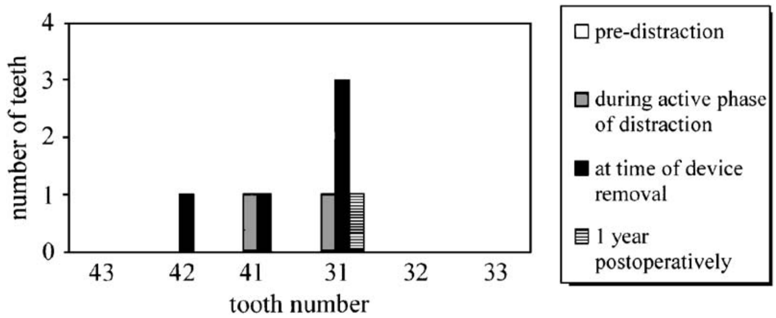

Figure 4 – Teeth not responding to cold testing.

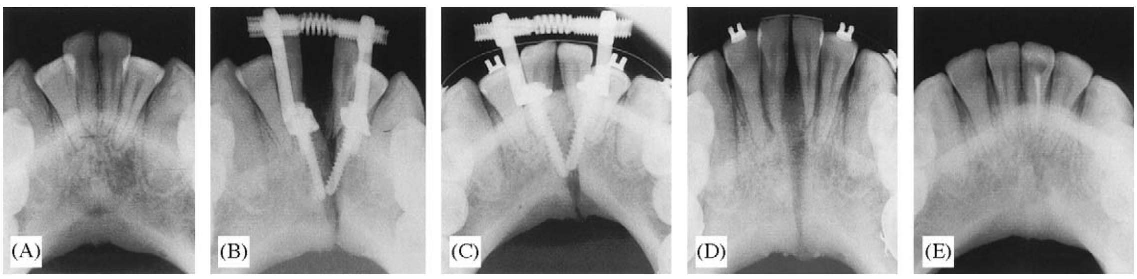

Figure 5 – Case in which the midline osteotomy could not avoid apicectomy of a central incisor. The amount of osteodistraction was greater at the coronal level than at the caudal level. Such differential distraction was seen in few cases. The patients did not complain about temporomandibular joint distress, but besides keeping the chin width constant, there is no good biological reason not to do so. (A) pre-operative occlusal radiograph; (B) occlusal radiograph during distraction; (C) occlusal radiograph at the end of the consolidation period (2 months); (D) occlusal radiograph after 3 months; (E) occlusal radiograph 2 years post-operatively (note endodontic treatment of one central incisor).

not deal with the displeasing wide lateral vestibula and with the dogma that the intercanine distance cannot be increased permanently by orthodontic expansion. Anterior repositioning is only indicated when an increased overjet can be reduced. The off-step in the canine–premolar region necessitates orthodontic buccal displacement of the premolars in order to align the lower dental arch. Hence, the buccal cortex becomes an obstacle and can be the cause of relapse in the transverse dimension, of buccal root resorption and of compensated occlusion.

The central incisors, and to a lesser extent the lateral incisors, were displaced visually and tipped towards the midline during the active and consolidation phases. Such movement has been attributed to elastic traction of the transseptal fibres (*Bell* et al., 1999; *Del Santo* et al., 2000). The exact magnitude of osteodistraction at the skeletal level was not measured in this series. Hence, the mesial drift of the front teeth could not be calculated. The impression was that the increase in intercanine distance gained by osteodistraction, was somewhat reduced by a mesial drift of the canine teeth during the distraction and consolidation periods. For this reason the technique was modified to install a fixed orthodontic device early in the consolidation period, and not following removal of the distractor some 2 months later as was planned initially.

Tooth-borne symphyseal distractors tend to procline incisor teeth not fixed by an orthodontic device, and *Del Santo* et al. (2000) attribute this to the antero-lateral rotational effect of the distraction. Similar movements were found in this study where a bone-borne distractor was used. This position can be explained by the barricade function of the labially placed distractor against pressure from the lips.

Perhaps the most important feature of TMD is its increased elasticity in the axial plane, allowing for rotation at the joints (*Mommaerts*, 2001). There are reports on absence of TMJ symptoms after anterior transmandibular osteodistraction (when none existed before) with the use of both tooth-borne and bone-borne distractors (*Weil* et al., 1997; *Kewitt* and *Van Sickels*, 1999; *Braun* et al., 2002). However, *Braun* et al. (2002) noted that in all 12 patients in their study (10 tooth-borne, 2 bone-borne), each mandibular half was displaced linearly in proportion to the amount of targeted osteodistraction. They state that the TMJ appear to accommodate these displacements. *Samchukov* et al. (2001) are of the opinion that from a biomechanical point of view, a hinge mechanism has to be foreseen in a symphyseal distractor. Computer simulation has demonstrated that for every 1-mm of anterior transmandibular osteodistraction the condyles rotate 0.34 degrees if the distractor allows for this rotation (*Samchukov* et al., 1998), and if the condylar axis is taken as fixed. When this static concept was transposed to this series, pure rotation in the condylar axis would account for 2 degrees (5.9×0.34) of rotation. However, the mean rotation in this series was calculated to be 9.38 degrees. The discrepancy can be explained by laxity of the temporomandibular joint, and rotational movements in the frontal plane. Rotation is not completely harmless and can result in minor and atypical morphological changes in the articular cartilage (*Harper* et al., 1997).

Several different professionals (periodontists, general dentists, surgical trainees) were involved in the pocket measurements, perhaps also reducing their validity. Pre-distraction values (depths increasing from central incisors towards canine teeth) were in concordance with reference depth values reported in the periodontal literature. An important increase in central incisor pocket depth was observed after the consolidation period. This is likely to be due to pseudopocket formation, explained by insufficient hygiene behind the distractor. At the 1-year follow-up appointment pocket depths were reduced to normal values, even with orthodontic appliances in situ. Periodontal recession was only seen at the end of active distraction, and not at the end of the consolidation period.

The increased mobility of the canine and lateral incisor teeth compared to the central incisors in the consolidation phase can be attributed to late migration. Migration implies that strain is present, probably due to increased tension in the transseptal fibre system. Increased mobility is the resulting biological response of the periodontal ligament, as occurring during any orthodontic tooth movement (*Tanne* et al., 1998). The dramatically increased mobility of the central incisors during the active phase of distraction was thought to be caused by rapid migration into the immature callus ('walking tooth' phenomenon). The median osteotomy may weaken or practically destroy the thin lamina dura between both central incisors. Mean mobility of the central incisors dropped to the degree of both the canines and lateral incisors by the end of consolidation, probably because they became rooted in the ossifying callus. *Kewitt* and *Van Sickels* (1999) also noticed Class II mobility of central incisors in the post-operative phase and attributed it to the combination of an osteotomy close to a root, increased expansion, and orthodontic treatment.

The diminished response of the central incisors to cold testing may be related to the ongoing tooth migration in the consolidation phase, causing a state of 'apical contusion' with neurapraxia.

Some typical features of osteodistraction such as using bone fixation (*Guerrero*, 1990; *Guerrero* et al., 1997; *Weil* et al., 1997) and respecting the latency period (*Guerrero* et al., 1997; *Bell* et al., 1999; *Del Santo* et al., 2000) were introduced rather recently; it took 10 years to be introduced in symphyseal osteodistraction. The only feature more quickly adopted was the osteodistraction rate of 1-mm per day (*Guerrero* et al., 1997; *Harper* et al., 1997; *Bell* et al., 1999; *Braun* et al., 2002; *Conley* and *Legan*, 2003; *Mussa* and *Smith*, 2003). Some authors claimed recently that slowing down the rate would lead to premature ossification (*Conley* and *Legan*, 2003; *Mussa* and *Smith*, 2003). Others presume that reducing the rate would be beneficial for the articular cartilage (*Harper* et al., 1997). The TMD device used in these patients was completely bone anchored. Furthermore a latency period of 7 days was respected and one activation 0.5-mm per day carried out. No premature ossification or temporomandibular joint symptoms was noticed in these patients.

Presurgical orthodontics to separate the roots in preparation for an osteotomy as described by *Mussa* and *Smith* (2003), was not used in any case. *Conley* and *Legan* (2003) mention that separation of the roots of the central incisors may require diverging of the roots of the lateral incisors first, and then movement of the central incisor roots into the newly available space. *Dorfman* and *Turvey* (1979) have suggested that 3–5 mm space between the apices of the teeth is necessary to safely perform an interdental osteotomy, without compromising periodontal health or tooth vitality. After the active phase of osteodistraction, the roots of the lateral and central incisors then need to be moved back medially. This back and forth movement could result in unnecessary root blunting and prolonged treatment time. It is still unknown if bone regeneration will or will not occur adjacent to a root with an exposed surface. The 2-mm separation of the bony edges at the time of osteotomy, with consequent detachment of the soft periodontal tissues is (probably) more likely to have caused this phenomenon in the animal experiments of *Bell* et al. (1999). It is possible that reattachment of the junctional epithelium at the original level occurred at a later stage, since these authors did not observe pathological pockets. Together with *Guerrero* et al. (1997) and *Kewitt* and *Van Sickels* (1999), it is thought that keeping the gingival ligament intact is important to avoid pathological pockets and loss of crestal height. Paramedian osteotomies were proposed by *Guerrero* et al. (1997), and stepwise by *Mommaerts* (2001), *Conley* and *Legan* (2003), and *Mommaerts* et al. (2003). The space between the roots of the central incisors can be very small and there is a risk of inadvertent apicectomy, as in one of our cases, and in two cases of *Kewitt* and *Van Sickels* (1999).

Although the two rods being positioned one above the other decrease elasticity in the frontal plane, micromovements still occur when patients eat and talk. In the orthopaedic literature, the importance of rigidity to avoid pseudarthrosis is stressed. However, in the maxillofacial literature it is claimed that micromovement is more likely to stimulate osteogenesis (*Bell* et al., 1999).

According to *Cousley* and *Jones* (1999) the cause of crowding in the anterior and middle apical area is multifactorial, and extractions (2 premolars, 1 incisor) or interproximal crown reduction with incisor proclination, are viable options in patients with moderate crowding predominantly in the mandible. We do not agree with these authors that the only indication for anterior transmandibular osteodistraction is a scissor bite (lingual occlusion). All of the patients in the study group received maxillary plus mandibular expansion, the main indications being major crowding in both jaws, and large buccal corridors (wide posterior vestibula) (*Mommaerts* et al., 2004).

CONCLUSION

The transmandibular distractor with a resilient central part facilitates rotation at the condyles and causes less lateral displacement than the more rigid symphyseal distractors. In this study, the front teeth moved medially in the active and consolidation phases. Pockets around the front teeth increased in depth during the consolidation period because the distractor compromised oral hygiene. One year post-operatively pocket depth had normalized. The front teeth became temporarily mobile, the central incisors in the active distraction phase and the canines in the consolidation phase. Cold sensitivity was temporarily lost in about 10% of the tested front teeth. The central incisors were mainly affected and the phenomenon may be explained by 'apical contusion'. One apicectomy necessitated root canal treatment. For this reason a step-osteotomy may be the preferred design.

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