Long-term (6.5 years) follow-up of mandibular midline distraction

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ABSTRACT

To assess the long-term stability and biomechanical effects of mandibular midline distraction (MMD), a prospective observational study was conducted with a retrospective cohort. Included were 17 MMD patients, of whom 9 completed the long-term follow-up with a mean of 6.5 years. In all patients a bone-borne distractor was used.

Dental casts and posterior-anterior (PA) cephalograms were taken at fixed time points: pre-operative (T1), directly post-distraction (T2), 1-year post-operative (T3) and long-term follow-up (T4). Inter canine (ICD), inter first premolar (IPMD), inter first molar (IMD) distances and arch length (AL) were measured on dental casts. From the PA cephalograms intercondyle distance (ID) and the ramal angle (RA) were obtained. A significant and sustained widening was observed in most measurements. The greatest overall transverse expansion (T1-T4) occurred in the IPMD (4.1 ± 0.76 mm, $P < 0.05$), the ICD, IMD and AL increased respectively: 2.0 ± 0.72mm, 3.8 ± 0.82mm and 3.5 ± 0.82mm. The ID did not change significant ($P > 0.05$) during all phases of the study. An increase of RA was observed initially, however, no difference was noted on the long-term. This study showed that MMD is a stable method to expand the mandible, with no skeletal effect on the temporomandibular joint.

INTRODUCTION

Transverse mandibular discrepancies manifest in anterior and posterior crowding, and uni- or bilateral crossbite. This can be prominent in patients with congenital deformities such as Treacher Collins syndrome, Apert syndrome, Crouzon syndrome, Nager syndrome. However, it can be present in non-syndromal patients as well. Traditionally, transverse discrepancies are treated with orthodontic appliances and/or teeth extractions. The intermaxillary suture can be expanded using orthodontic appliances until around 15 years (Wehrbein and Yildizhan 2001). The mandibular symphysis however, closes at the age of 1, therefore expanding the mandible without surgical intervention is impossible (Little 1990; Sperber 2001).

In the early 90s of last century distraction techniques were introduced for the facial skeleton and new treatment options became available (McCarthy et al. 1992; Guerrero et al. 1997; Koudstaal et al. 2005). Mandibular midline distraction (MMD) is the technique whereby the mandible is widened using distraction. An osteotomy is performed and a distractor is attached on both sides of the osteotomy, following the activation of the distractor both histio- and osteogenesis occur.

Solitary MMD can be indicated when the transversal discrepancy only affects the mandible. However, transversal discrepancies often affect both the maxilla and the mandible, and bimaxillary expansion (BiMEx) is indicated to maintain proper occlusion.

The distractor itself can be attached to the bone, the teeth, or a combination of both. Biomechanical aspects of distractors are important as they influence the outcome of distraction in the long-term, specifically relapse (Alkan et al. 2007). Although short-term series on MMD have been reported, long-term clinical studies are lacking on the biomechanical effects of bone-borne distractors in MMD. The primary objective of this study is to evaluate the long-term biomechanical effects of MMD on dental and skeletal level.

MATERIAL AND METHODS

A prospective observational study with a retrospective cohort was performed at the Erasmus University Medical Centre. The patient cohort was derived from patients included in a prospective study on surgically assisted rapid maxillary expansion (SARME) who also underwent MMD in one operation, BiMEx (Koudstaal et al. 2009). Approval of the Standing Committee on Ethical Research in Humans of the Erasmus University Medical Centre Rotterdam was obtained (MEC 2011-265). All patients were re-invited to our clinic for the long-term follow-up. All participating patients underwent BiMEx surgery before 2008. The surgical technique was similar to what Mommaerts et al. described and two different bone-borne distractor device were used, namely: TMD-flex and the

Rotterdam Mandibular Distractor (Mommaerts 2001; de Gijt et al. 2012). During this study, dental casts and posterior-anterior (PA) cephalograms were obtained at fixed time points: pre-operative (T1), direct post-distraction (T2), 1-year post-operative (T3) and the long-term follow-up (T4).

Inclusion criteria for this study were:

- Mandibular discrepancy (mandibular anterior and/or posterior crowding, uni- or bilateral crossbite)
- Age 18 years or above
- Treated before 2008

Exclusion criteria were congenital craniofacial deformity patients, a history of radiation therapy in the area of interest and mental retardation.

Dental cast study

On the mandibular dental cast the following distances were measured; inter canine (ICD), inter first pre-molar (IPMD) and inter first molar (IMD), further the arch length (AL) was obtained using the method described by Chung et al. (Chung and Tae 2007). For ICD, IPMD and IMD the tip of the (disto-)buccal cusps were used (Fig. 1). The AP was defined as the sum of the left and right distance from the mesial anatomic contact points of the mandibular first permanent molars to the contact point of the central incisors or to the midpoint between the central incisor contacts, if spaced during distraction (Fig. 1).

All measurements were performed using an electronic digital caliper (Kraftixx®, art.0906-90) with an accuracy of 0.02 mm on the dental cast study models.

Posterior-anterior cephalograms analysis

Cephalometric analyses were performed on PA cephalograms, see figure 2. To assess the effect of MMD on the mandible the ramal angle (RA) and the intercondyle distance (ID) were measured (Gunbay et al. 2009).

The landmarks used in this analysis were: the most lateral part of left and right condyle head (Lco and Rco); left and right gonion (Lgo and Rgo). ID was obtained by measuring the distance between Rco and Lco. By creating a line from the lateral condyle to gonion and measure the angle between the left and right side RA was acquired (Lco-Lgo/Rco-Rgo). The distance between the left and right zygomatic process (Lzp and Rzp) was used as a control measurement. All measurements were digitally performed with iSite Enterprise (Phillips Healthcare Informatics, Foster City, California, United States of America).

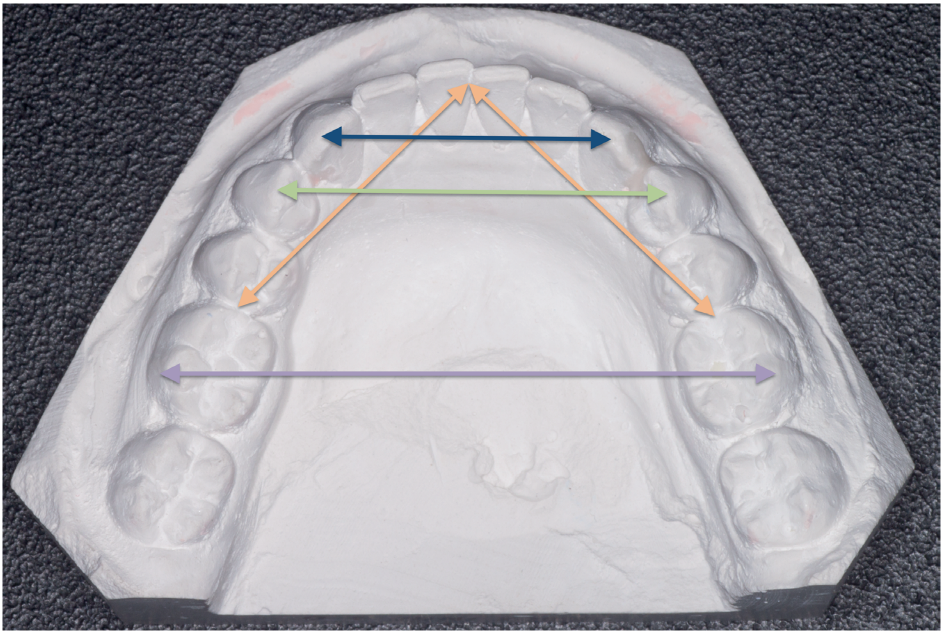

Figure 1. Blue line: ICD; green line: IPMD; purple line: IMD; orange line: AL.

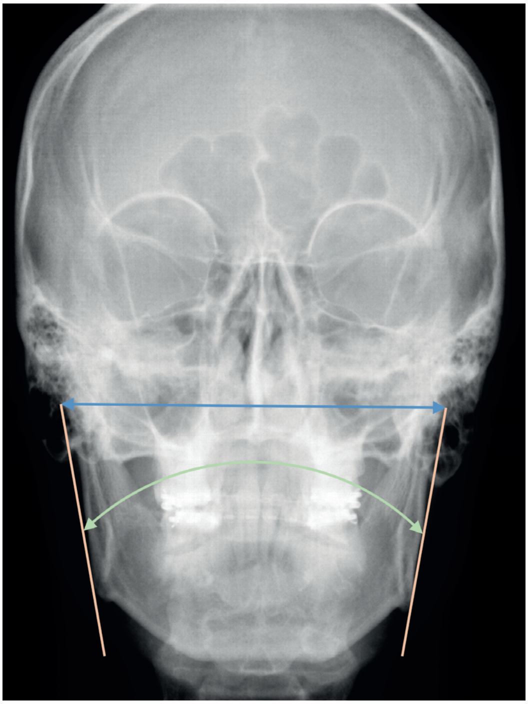

Figure 2. PA cephalogram analysis. Blue line: intercondyle distance; green line: ramal angle; orange lines: line from lateral part of the condyle and gonion.

Statistical analysis

The statistical analysis was performed in collaboration with the Department of Biostatistics of the Erasmus Medical Centre Rotterdam. The analyses were performed using the Statistical Package of the Social Sciences (version 20.0, SPSS Inc, IBM Corporation). All measurements were performed twice by the author and the mean value was used for the analysis.

The longitudinal changes were evaluated using Mixed Models ANOVA, with a Bonferroni correction. Because of the fact that during the follow-up period, other surgeries might be performed, bilateral sagittal split osteotomy and teeth extractions were added as fixed factors in respectively the PA cephalogram analysis and the dental cast analysis. A P-value of < 0.05 was considered significant.

Reliability analysis

To assess inter- and intra-observer agreement an intraclass correlation coefficient (ICC) was obtained. Therefore, for the inter-observer reliability all measurements were also done by the second author. An ICC value of ≥ 0.9 was considered reliable.

RESULTS

In this study 17 MMD patients were included. The age at the moment of surgery ranged from 13 to 43 years and all patients underwent SARME. For the long-term follow-up 9 patients returned to our department. See table 1 for the baseline characteristics of all the patients.

Table 1. Baseline patient characteristics.

	T1-T3	T4
Number of patients	17	9
Mean age	26 (range: 13-43)	28 (range: 13-43)
Male:Female	9:8	3:6

Dental cast study

In table 2 and 4 and figure 3-6 the complete results of the dental cast study measurements are listed. All measurements were significantly influenced by time ($P < 0.05$). Compared to the pre-operative time point (T1) all transverse measurements showed an increase. Regarding the first year follow-up all transverse distances were significant expanded by MMD ($P < 0.05$). The greatest expansion (T1-T2) was seen in the IPMD region: 4.9 mm ($P < 0.05$), ICD and IMD increased respectively 4.9 and 2.4 mm ($P < 0.05$). After the first year of treatment (T3-T2) the ICD decreased 1.5 mm ($P > 0.05$), all other measurements slightly increased ($P > 0.05$).

Table 2. Dental cast study.

	T1		T2		T3		T4		Time
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	P-value
ICD	20.0	1.11	24.4	1.33	22.9	1.09	22.0	1.03	0.03*
IPMD	26.5	1.10	31.4	1.13	31.7	1.03	30.6	0.88	< 0.001*
IMD	42.3	0.99	44.8	1.01	45.2	0.94	46.1	1.26	< 0.001*
AL	53.6	2.32	58.1	2.66	58.7	2.18	57.1	1.98	< 0.001*
Follow-up (months)	-2		2		13		78		

Distances in mm: ICD: intercanine distance, IPMD: interpremolar distance, IMD: intermolar distance, AL: arch length. S.E.: standard error, * = P < 0,05.

Table 3. Posterior-anterior cephalometry.

	T1		T2		T3		T4		Time
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	P-value
ID	122.1	1.88	121.0	2.02	121.6	1.97	122.0	1.88	0.17
RA	24.0°	1.34	26.9°	1.35	25.2°	1.36	24.0°	1.43	0.002*
ZZ	135.4	1.88	135.1	1.71	135.5	1.66	135.8	1.53	0.52

Distances in mm: ID: intercondyle distance, ZZ: interzygoma distance. Angle: RA: ramal angle. S.E.: standard error, * = P < 0,05.

Concerning the long-term follow-up (T1-T4) all measurements showed a significant increase (P > 0.05), only the ICD was not significantly increased (P < 0.05). No significant relapse was found between T3-T4 in all measurements (P > 0.05).

The arch length increased after distraction and orthodontic aligning, however during the long-term follow-up, T3-T4, relapse occurred though not significant (-1.6 mm, P > 0.05).

Posterior-anterior cephalogram analysis

In table 3 and 4 and figure 6 and 7 the results of the PA cephalogram measurements are listed. The ID did not change significantly (P > 0.05) at any of the time phases. The cephalometric analysis showed a significant (P < 0.05) increase of the ramal angle between T1 andT2. However, the medium (T3) and long-term follow-up (T4) showed no significant difference with the initial ramal angle (T1). The inter zygomatic process distance did not change between the PA cephalograms over all the time phases indicating a reliable measurement.

Reliability analysis

The ICC for each separate measurement, both inter- and intra-observer, were ≥0.9 indicating that the measurements were reliable.

Table 4. Longitudinal results.

	T1-T2			T1-T3			T1-T4		
	Mean	S.E.	P-value	Mean	S.E.	P-value	Mean	S.E.	P-value
ICD	4.4	0.60	<0.001*	2.9	0.52	<0.001*	2.0	0.72	0.20
IPMD	4.9	0.76	<0.001*	5.2	0.69	<0.001*	4.1	0.76	<0.001*
IMD	2.4	0.42	<0.001*	2.9	0.46	<0.001*	3.8	0.82	0.002*
AL	4.6	1.03	0.002*	5.1	1.11	0.001*	3.5	0.35	0.35
ID	-0.4	0.77	0.94	-0.6	0.79	1.00	-0.1	1.08	1.00
RA	-1.1°	0.67	0.001*	1.2°	0.72	0.67	0.0°	1.09	1.00

	T4-T3			T3-T2		
	Mean	S.E.	P-value	Mean	S.E.	P-value
ICD	-0.9	0.59	1.00	-1.5	0.62	0.16
IPMD	-1.0	0.70	0.96	0.3	0.72	1.00
IMD	0.9	0.43	0.32	0.4	0.30	1.00
AL	-1.6	0.81	0.81	0.6	1.10	1.00
ID	0.5	1.06	1.00	0.6	0.81	1.00
RA	-1.2°	1.05	1.00	-1.7°	0.72	0.15

Distances in mm: ICD: intercanine distance, IPMD: interpremolar distance, IMD: intermolar distance, AL: arch length, ID: intercondyle distance. Angle: RA: ramal angle. S.E.: standard error, * = P < 0,05.

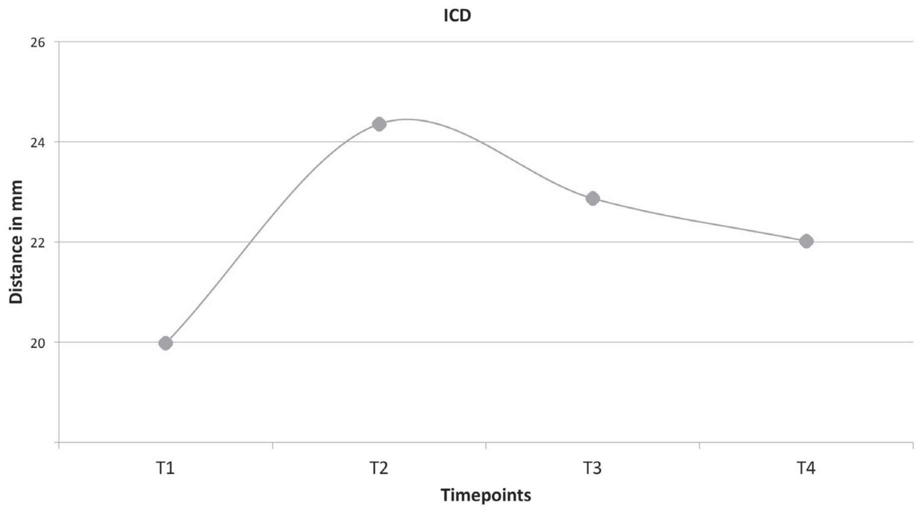

Figure 3. Inter canine distance.

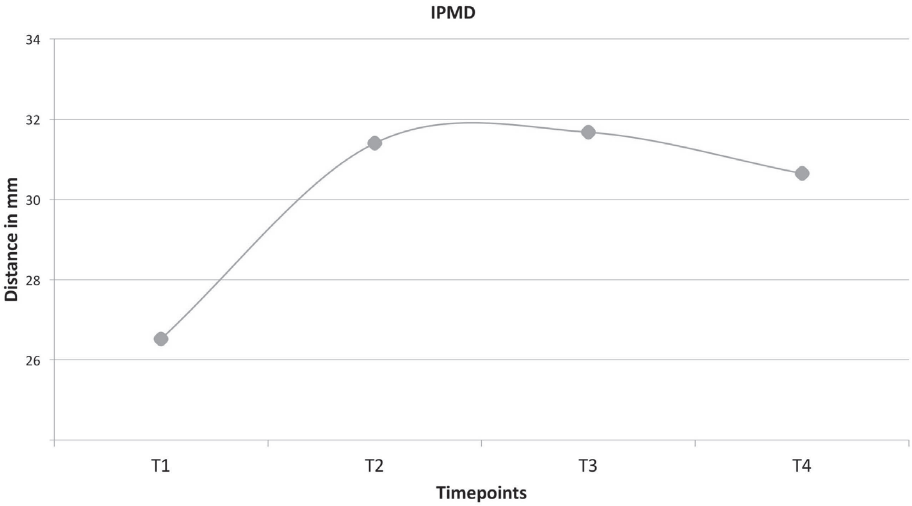

Figure 4. Inter premolar distance.

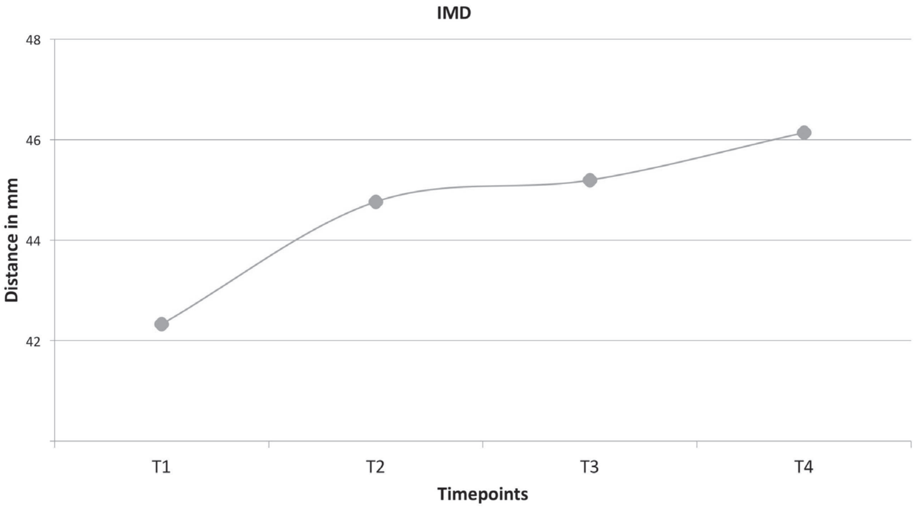

Figure 5. Inter molar distance.

DISCUSSION

With the introduction of MMD a surgical procedure to widen the mandible became available to overcome large transverse mandibular discrepancies without having to extract healthy teeth (Guerrero et al. 1997). The aim of this study is to assess the stability and relapse of MMD on the long-term.

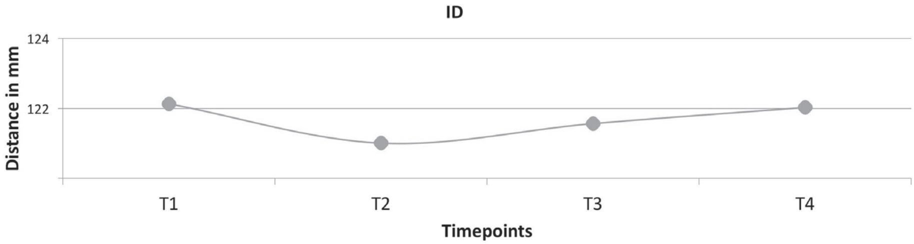

Figure 6. Intercondyle distance

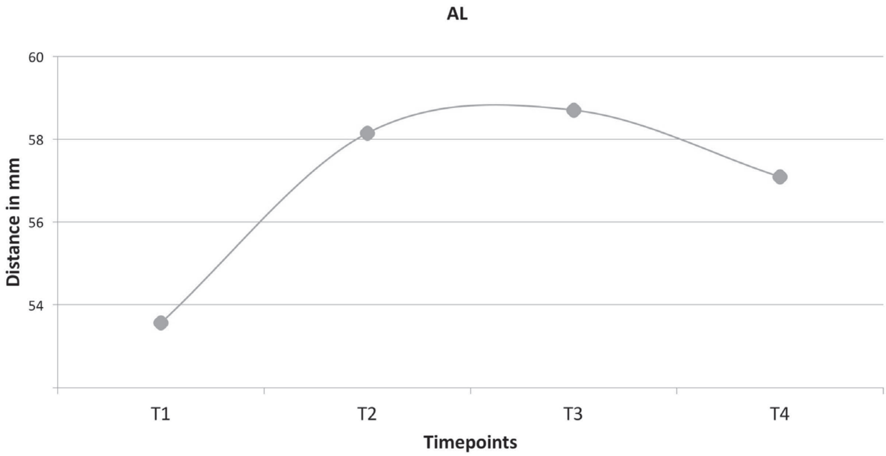

Figure 7. Arch length.

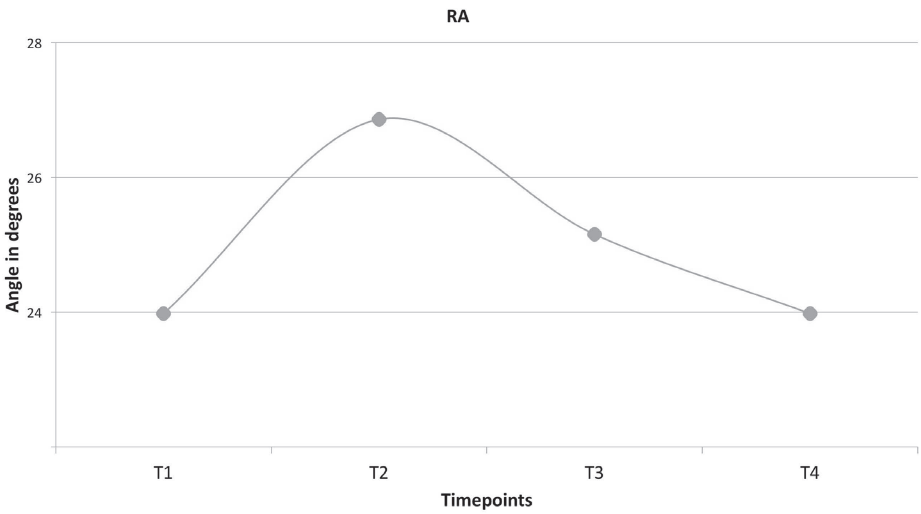

Figure 8. Ramal angle.

Different studies with stable results have been published since the introduction (Del Santo et al. 2000; Malkoc et al. 2006; Chung and Tae 2007; Gunbay et al. 2009; King et al. 2012). Since the procedure is relatively new, the follow-up period of these studies was limited to a period of 1 to 3 years post-surgery. At this time, in most cases, orthodontic treatment has just finished and the stability of the surgical procedure itself is not proven by these studies. Therefore, longer follow-up periods are necessary to address stability of the procedure. Only King et al. conducted a study with a follow-up time of more than 3 years.

In literature, relative consensus is available concerning the surgical technique and distraction pattern. However, there is no consensus regarding the use of a particular distractor device. Three types of distractors are known namely, bone-borne, tooth-borne and hybrid. The main difference between the appliances is the position on which the distractors are fixed; the bone-borne devices are fixed to the bone, the tooth-borne to teeth and the hybrid to both. As a result of the different fixation positions different biomechanical effects can be expected. In theory, the benefit of a bone-borne distractor and to a lesser extend the hybrid-distractor, is the appliance of the distractor forces at basal bone level (Conley and Legan 2003). A more parallel expansion of the hemi-mandibles is expected. A more coronal application of the vector, in the case of a tooth-borne device, can cause angulation between the hemi-mandibles and thus a less parallel distraction gap. This might result in a less stable result of the expansion. Furthermore, the rigidity of the distractor appliances differs and this might influence the direction of the applied forces (Mommaerts 2001; de Gijt et al. 2012). In this study both rigid and less rigid bone-borne distractors were used. To our knowledge, the study we present has the longest follow-up of MMD patients using a bone-borne distractor, with a relatively large sample.

The results show that after the initial distraction (T1-T2) a significant increase in width is achieved in all dental cast measurements. Initially the greatest increase can be found in the pre-molar and canine region. Following orthodontic treatment, a decrease of ICD is observed. This decrease in distance is the result of the orthodontic treatment moving the canines medially in the direction of the distraction gap. At premolar and molar level teeth this effect is smaller resulting in a smaller decrease of width. For the 1-year follow-up (T3) these results are similar to what is previously described in literature (Del Santo et al. 2000; Chung and Tae 2007; Gunbay et al. 2009; King et al. 2012). In the long-term no significant relapse was found in the dental cast analysis between T3 and T4 indicating a stable result. In literature, only King et al. conducted a long-term follow-up study to assess the stability of MMD with the use of a hybrid-distractor (King et al. 2012). The results of the King et al. study indicate a stable long-term result after treatment. Because of the different time-points used in their study it is difficult to directly compare the results of this study with the study of King et al. Although similar results are presented in their study, it appears that, especially in the premolar region more relapse is observed than in our patient group in the post-distraction and post-treatment phase. This indicates that more tooth movement was needed during the treatment. It was not explained if this was due to the fact that pre-distraction expansion was obtained by orthodontic forces and thus more dentoalveolar expansion. It is important to limit dentoalveolar expansion as it would increase the risk of fenestration and periodontal problems (Proffit et al. 2003).

Concerning the arch length, a significant increase between T1 and T3 of 5.1 mm was achieved which remained stable until T4. Although the arch length decreased during T3-T4 this was not significant. Compared to King et al. more arch length was gained (T_{pre-op}-$T_{long-term}$: 1.5 mm $P > 0.05$, this study: 3.6 mm $P > 0.05$). This might indicate a more anterior width increase with the use of a bone-borne device.

A cephalometric analysis was performed to analyse the effect of MMD on the temporomandibular joint. Only minor and non-significant differences were found in ID. King et al. have shown non-significant changes in ID (King et al. 2012). Noticeably, between the pre-distraction and post-distraction time points a more lateral movement of the condyle is reported. This is in concordance with the fine element study of Kim et al. which states that with the use of a hybrid-distractor, the distraction forces are located more cranially and distally, similar to a tooth-borne device (Kim et al. 2012). Therefore, the condyles are pushed further lateral in hybrid and tooth-borne devices than bone-borne devices. This could create a bigger force in the region of masticatory muscles and the temporomandibular joints. However, in this study, initially, the ramal angle did increase during the distraction phase nevertheless the ramus and condyle adapted to the new situation and the ramal angle rapidly decreased after the distraction phase. Since this study only used PA-cephalograms, new imaging techniques would give more insight on the effect of MMD on the temporomandibular joint. To our knowledge, in literature no reports of severe temporomandibular joint symptoms after MMD are reported. Further research would objectify the effects of the different distractors on the temporomandibular joint.

Although the choice of the distractor might be influenced by the biomechanical aspects, other aspects must be taken in account. The patients' experience of the distractor can differ as a result of the different positions of the distractor. A tooth-borne distractor is positioned lingual of the dental arch close to the tongue and this might be uncomfortable for the patient as it can interfere with tongue function (speech, swallowing et cetera.). The buccal position of the hybrid and bone-borne devices might harm the buccal mucosa, is more prone to wound dehiscence and can be a visible and painful volume underneath the lip. Tooth-borne and hybrid devices are always custom-made and therefore more expensive. However, the need for a second procedure to remove the hybrid or bone-borne distractor is both an extra physical and financial burden for the patient and the health care system. To resolve the scientific debate on the use of a specific distractor type, a randomized controlled trial should be performed.

Major advantages of this study are the long-term follow-up period, a large patient cohort and the nature of this prospectively followed group. As result of the long follow-up period, the use of cone-beam computer tomography (CBCT) or conventional multi-slice computer tomography (MSCT) were not implemented during the initial research design. Such a design would give even more insight in the biomechanical aspect of MMD. For future research the incorporation of these new image modalities would be advisable.

CONCLUSION

This study presents the long-term follow-up of a patient cohort treated with MMD using a bone-borne distractor device. The results show a stable dental result after 6.5 years, showing it to be a reliable treatment option for transverse discrepancies. Furthermore, this study shows that bone-borne devices have no positional effect on the temporomandibular joint indicating minimal risk of craniomandibular dysfunction following MMD. The choice of the distractor depends on more factors, including surgeons' and orthodontists' preference and patient friendliness. More research is necessary with state-of-the-art imaging techniques such as CBCT and a randomized controlled trial design.

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