6,5 years follow up of surgically assisted rapid maxillary expansion (SARME), skeletal and dental effects

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ABSTRACT

Surgically-assisted rapid maxillary expansion (SARME) is a technique used to widen the maxilla, and we present the results of our long-term follow up (6.5 years). Seventeen patients who had been treated with SARME and prospectively followed were invited for long-term follow up using dental casts and posteroanterior cephalograms. The following measurements were made on the dental casts: transverse distances at canine, premolar, and molar level, length of the arch, and width and depth of the palate at premolar and molar level. The distance between the left and right nasal bases and the widening of the inferior maxilla were measured on the posteroanterior cephalograms. Boneborne and toothborne distractors were used in 8 and 9 patients, respectively. In the study of dental casts, there was a significant increase in transverse width in the canine ($P < 0.001$), premolar ($P < 0.001$) and molar ($P = 0,001$) and these remained stable in the long term. The arch length did not increase significantly, but the palatal width increased significantly in the premolar ($P < 0.001$) and molar ($P = 0.001$) regions. No effect was seen in palatal depth. On the posteroanterior cephalograms the width of the inferior part of the maxilla was increased, but not significantly so. There were no significant changes at the nasal base. We conclude that SARME is a predictable technique to widen the maxilla in the long term.

INTRODUCTION

Indications for surgically-assisted rapid maxillary expansion (SARME) include transverse discrepancies, which can present in both syndromic and non-syndromic patients. Clinically, transverse discrepancies include a unilateral or bilateral crossbite, buccal corridors, anterior crowding, buccal tipping of the maxillary molars, and lingual tipping of the mandibular molars. Congenital deformities that may affect the maxillary width include: clefts, frontonasal dysplasia, Apert syndrome, Pfeiffer syndrome, and Saethre-Chotzen syndrome (acrocephalosyndactyly type III).[1]

Successful skeletal maxillary expansion can be achieved with conventional orthodontic rapid maxillary expansion, but after the age of about 15 years surgical intervention may be necessary to expand the maxilla successfully. It has been suggested that the heavy interdigitation of the midpalatal and circum-maxillary sutures may be why it is resistant to separation.[2–4] Recently, successful expansion using bone anchors has been reported.[18] Different operations have also been described, including a bilateral corticotomy. In addition, a midline osteotomy may be necessary. Some authors favour release of the pterygoid plates, and some do not.[19]

After the osteotomies the expansion is initiated with a distractor, two different types of which are available: boneborne (applied to the maxillary bone) and toothborne (fixed to two or more teeth on each side of the maxilla). No significant differences were found between the two in a prospective, randomised, controlled trial.[5] As little is known about the effects of SARME in the long term, we have focused on dental and skeletal tissue.

MATERIAL AND METHODS

An observational study was done at the Erasmus University Medical Centre, Rotterdam The Netherlands. The group of patients was derived from the prospective study on SARME by Koudstaal et al.[5] After approval had been given by the Standing Committee on Ethical Research in Humans of the Erasmus University Medical Centre Rotterdam in 2011 (MEC 2011-265), all patients were invited by mail to return to our clinic for long-term follow up. All patients had been operated on before 2008. During the initial study, dental casts and posteroanterior cephalograms were obtained at fixed time points: preoperatively (T1), immediately postoperatively (T2), and one year postoperatively (T3). Only patients who returned for the long-term follow up were included in the study. Dental casts and posteroanterior cephalograms were obtained for the long-term follow up (T4).

Surgical technique

The precise surgical technique and specific types of distractors used during the original study were described by Koudstaal et al.[5]

Dental cast study

On the dental cast the following transverse distances were measured: intercanine, interfirst premolar, and interfirst molar. The perimeter of the arch, and width and depth of the palate were also recorded. The depth and width of the palate were measured at the first premolar and first molar level. Because the distractor was in place at T2, we made no measurements at this time. For the intercanine, interfirst premolar, and interfirst molars, the tips of the (disto)buccal cusps were used (Fig. 1).[5] To measure the perimeter of the arch, the distances between the contact points on the mesial surface of the first molar, the mesial surface of the first premolar, and the distal surface of the central incisor on both sides were added together.[6] T0o assess the width and depth of the palate we used the technique described by Northway et al.[7] All measurements on the dental casts were made with electronic digital calipers that were accurate to 0.02 mm (Kraftixx®, art.0906-90, kwb Germany GmbH).

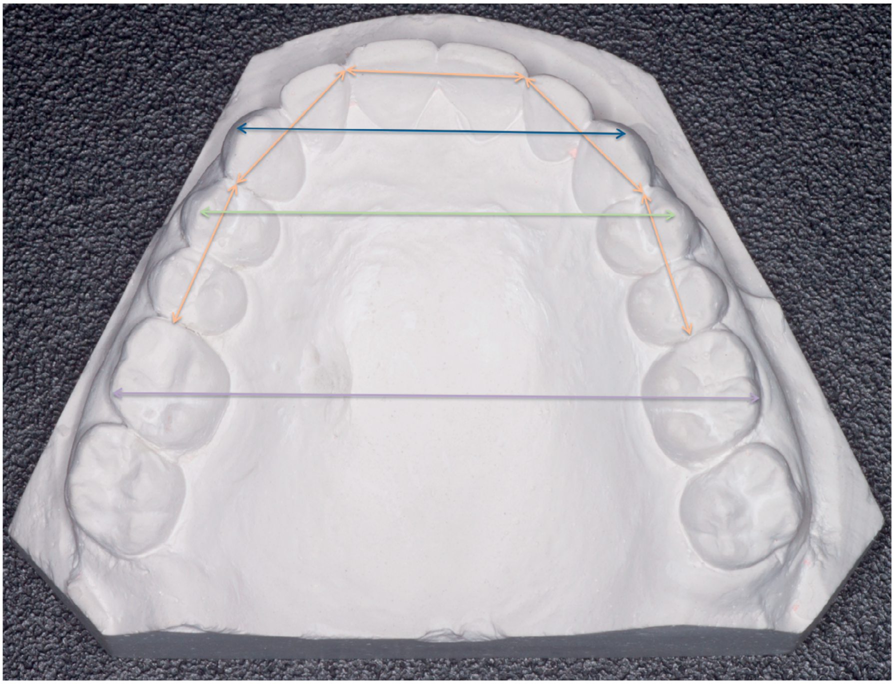

Figure 1. Dental cast analysis. Blue line = intercanine distance, green line = interpremolar distance, purple line = intermolar distance, and orange line = arch length.

Analysis of posteroanterior cephalograms

To evaluate the skeletal response when the maxilla was expanded we made cephalometric analyses on posteroanterior cephalograms. To assess widening of the nasal floor we measured the distance between the lowest points of the left and right piriform apertures (NN). To assess widening of the inferior part of the maxilla, we measured the distance between the intersection of the molar and the alveolar processes on the left and right (MM). The distance between the left and right zygomatic processes (ZZ) were used as controls. All measurements were made digitally with Sidexis (Phillips, Eindhoven,The Netherlands).

Statistical analysis

The statistical analysis (in association with the department of Biostatistics of the Erasmus Medical Centre, Rotterdam) was made using IBM SPSS Statistics for Windows (version 20.0, IBM Corp, Armonk, NY). All measurements were made twice by the authors and the mean value used for the analysis. The longitudinal changes were evaluated using a mixed models ANOVA, with a Bonferroni test. Because of the fact that other operations may have been necessary during the follow-up period, LeFort 1 osteotomy and extractions of teeth were added as fixed factors in the analysis of the posteroanterior cephalograms and the dental casts, respectively. Probabilities of less than 0.05 were accepted as significant.

Reliability analysis

To assess interobserver and intraobserver agreement we calculated an intraclass correlation coefficient (ICC). All measurements were also made by the second author. An ICC value of 0.9 or more was considered reliable.

RESULTS

Baseline characteristics

Seventeen of the original 42 patients contacted were included in the long-term follow up. The mean (range) age at operation was 31 (13-47) years, And the mean (range) long-term follow up was 6.5 (5-9) years. Both boneborne (n = 8) and toothborne (n = 9) distractors were used. The mean follow-up time points were 2 months preoperatively (T1), 2 months postoperatively (T2), 13 months postoperatively (T3), and 79 months (6.5 years) postoperatively (T4). Nine patients had mandibular midline distraction simultaneously with the SARME. Four patients had a le Fort I osteotomy during the follow-up period. No two or three piece osteotomies were done.

Dental cast study

Tables 1 and 2 show the complete results of the measurements of the dental casts. A transverse dental expansion was obtained in all regions (canine, premolar, and molar). The initial increase (T1-T2) was greatest in the premolar region (6.6 mm), while in the canine and molar regions it was 6.3 and

5.5 mm, respectively. After one year the expansion at the pre-molar level remained stable, but there were non-significant decreases in the canine (2.5 mm) and molar (1.3 mm) regions. During the long-term follow up there were small and non- significant decreases in all regions (Figs. 2–4).

Table 1. Distances.

	T1		T2		T3		T4		Time
	Mean (mm.)	S.E.	Mean (mm.)	S.E.	Mean (mm.)	S.E.	Mean (mm.)	S.E.	P-value
ICD	31.4	0.71	37.7	1.29	35.3	0.41	34.9	0.37	<0.001*
IPMD	35.7	0.93	42.3	0.92	42.7	0.61	42.0	0.63	<0.001*
IMD	46.8	1.24	52.3	1.14	51.0	0.83	50.8	0.78	<0.001*
AL	65.3	2.29	72.1	2.49	68.7	1.95	66.6	1.73	<0.001*
PWPM	13.0	1.1			16.0	0.89	16.7	0.71	<0.001*
PWMOL	15.6	0.99			18.5	0.82	18.4	0.63	<0.001*
PDPM	19.0	0.88			18.5	0.81	18.6	0.85	0.17
MM	60.6	1.39	63.0	0.85	62.9	0.99	61.8	0.98	0.007*
NN	17.5	1.75	18.1	1.40	18.2	1.25	18.2	1.52	0.91
Follow-up (months)	-2		2		13		78		

Dental cast study: ICD = Intercanine distance, IPMD = interpremolar distance, IMD = intermolar distance, AL = arch length, PWPM = palatal width at premo- lar level, PWMOL = premolar width at molar level, PDPM = palatal depth at premolar level, and PDMOL = palatal depth at molar level. Posterior-anterior cephalogram analysis, MM = intermolar distance, and NN = internasal base distance.

There was an initial significant increase in the length of the arch at T1-T2 of 6.9 mm (P < 0.001), but after a year it had reduced to only 3.5 mm, and at the end of the long-term follow up this had reduced to 2 mm.

There were significant and stable increases in the long- term width of the palate of 3.7 mm in the premolar region (P < 0.001) and 2.8 mm in the molar region (P = 0.001). No significant effect of SARME on the palatal depth was observed.

Analysis of posteroanterior cephalograms

Tables 1 and 2 show the complete results of the analysis of the posteroanterior cephalograms. In the molar region there was an initial increase of 2.4 mm (T1-T2), but between

Table 2. Longitudinal results.

	T1-T2			T1-T3			T1-T4		
	Mean (mm.)	S.E.	P-value	Mean (mm.)	S.E.	P-value	Mean (mm.)	S.E.	P-value
ICD	6.3	1.14	<0.001*	3.9	0.57	<0.001*	3.5	0.57	<0.001*
IPMD	6.6	0.81	<0.001*	7.0	0.67	<0.001*	6.3	0.69	<0.001*
IMD	5.5	0.89	<0.001*	4.2	0.81	<0.001*	4.0	0.83	0.001*
AP	6.9	1.18	<0.001*	3.4	1.01	0.013*	1.4	1.05	1.00
PWPM				3.0	0.93	0.015*	3.7	0.55	<0.001*
PWMOL				2.9	0.59	<0.001*	2.8	0.60	0.001*
PDPM				-0.5	0.29	0.225	-0.5	0.31	0.38
PDMOL				0.0	0.42	1.00	0.3	0.43	1.00
MM	2.4	0.82	0.063	2.3	0.73	0.046*	1.2	0.86	0.063
NN	0.6	1.08	1.00	0.7	1.08	1.00	0.8	1.16	1.00

	T2-T3			T4-T3		
	Mean (mm.)	S.E.	P-value	Mean (mm.)	S.E.	P-value
ICD	-2.5	1.16	0.23	-0.3	0.33	1.00
IPMD	0.4	0.71	1.00	-0.7	0.49	0.89
IMD	-1.3	0.78	06.1	-0.2	0.55	1.00
AP	-3.5	1.20	0.049*	-2.0	0.85	0.13
PWPM				0.6	0.74	1.00
PWMOL				-0.1	0.48	1.00
PDPM				0.0	0.29	1.00
PDMOL				0.3	0.38	1.00
MM	-0.1	0.26	1.00	-1.1	0.42	0.10
NN	0.1	0.78	1.00	0.1	1.01	1.00

Longitudinal results, dental cast study: ICD = ntercanine distance, IPMD = interpremolar distance, IMD = intermolar distance, AL = arch length, PWPM = palatal width at premolar level, PWMOL = premolar width at molar level, PDPM = palatal depth at premolar level, and PDMOL = palatal depth at molar level. Longitudinal results, posterior-anterior cephalogram analysis: MM = intermolar distance and NN = internasal base distance.

T1 and T4 the increase was small (1.2 mm) and not significant. SARME had no significant effect in the nasal region, and the control measurement between the zygomatic processes remained stable.

Reliability analysis

The ICC for each separate measurement were ≥ 0.9, which indicated that both interobserver and intraobserver measurements were reliable.

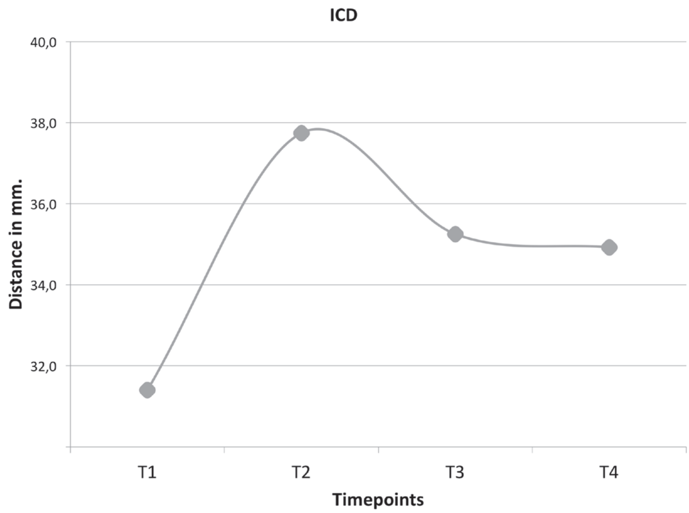

Figure 2. Inter canine distance.

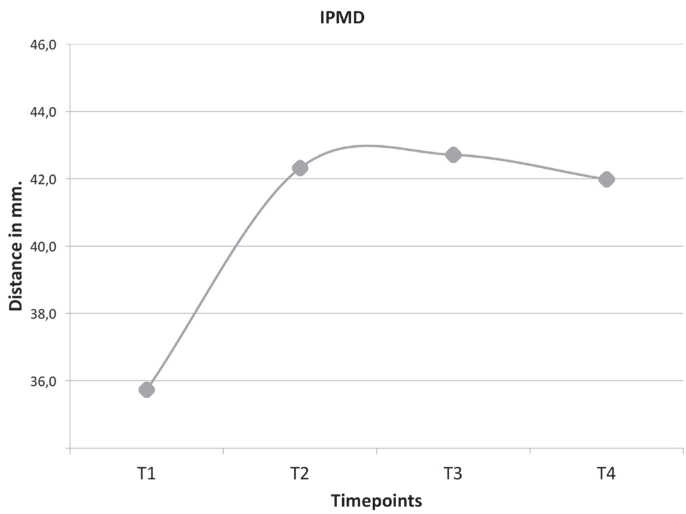

Figure 3. Inter-premolar distance.

DISCUSSION

SARME is a well-established and relatively safe technique used to widen the maxilla.[8,9] This study is a continuation of the study by Koudstaal et al about stability, tipping, and relapse between toothborne and boneborne distractors in SARME.[5] In the original study

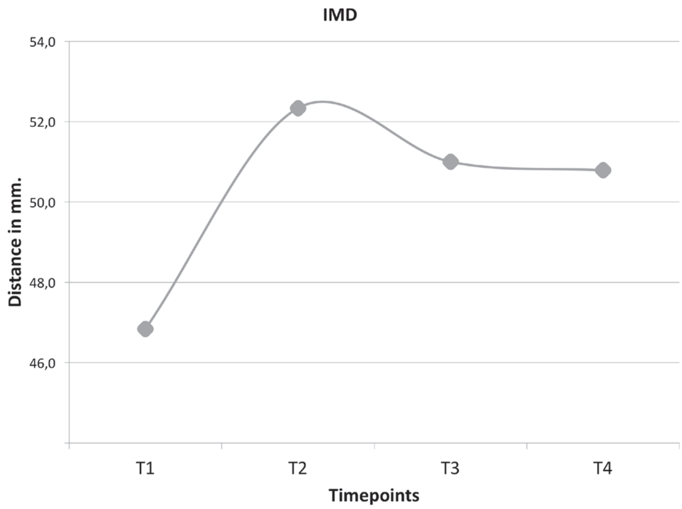

Figure 4. Inter molar distance.

there were no significant differences between the two types, and this has been substantiated by recent research.[10,11]

In our clinic this study caused us to move towards the almost exclusive use of tooth-borne distractors in non- syndromic patients with transverse maxillary hypoplasia. We would have preferred it if the study had included all the previous patients, but despite our efforts to invite as many patients as possible, the number who responded was too small to com- pare the two types of distractor. We do think, however, that the study gives a good perspective on the long-term effects of SARME in a prospectively-studied group of patients. Long- term follow-up studies of SARME do exist, but most of them have a relatively limited follow up or do not include a one-year postoperative time point. We have therefore attempted to obtain more insight into the dental and skeletal changes after SARME and orthodontic treatment.

To achieve a stable result from SARME it is necessary to achieve a solid bony framework for the dentition. Different bony structures resist effective maxillary expansion in patients who have ceased to grow, including the pterygoid plates, the zygomaticoalveolar crest, the piriform aperture and, to a lesser extent, the midpalatal suture.[12] With SARME some or all of these structures are released to be able to widen the maxilla. Surgeons differ in their operative techniques, with some advocating release of as much resistance as possible, and others being less invasive.[13] The greatest difference between the techniques is the use of osteotomy of the pterygoid plates. Biomechanically the release of the pterygoid plates weakens the most posterior resistance to expansion of the maxilla and therefore a more parallel widening pattern of the maxilla is to be expected.

The long-term results in the present study are in line with those of previous studies on the long-term effect of SARME on the widening of the maxilla.[14–16] Magnussen et al and Anttila et al described their long-term experiences with SARME, including ptyergoid disjunction.[14,16] No appreciable relapse was found after the orthodontic treatment had been completed, with a mean follow-up of 4.7 years for Anttila et al and 6.4 years for Magnussen et al.[14,16] We have shown that long-term stable results can be achieved without pterygoid disjunction.

Another aspect for debate is the type of distractor. Different distractors apply their forces differently, and create different vectors. As a toothborne distractor is fixed on to teeth it may cause orthodontic movement and, depending on the amount of dental response, this could lead to fenestration of the teeth, gingival recession, periodontal problems, resorption of roots, and dental tipping.[17] However, the one- point fixation of a boneborne distractor can cause rotation of the segments and asymmetrical widening, and also a second procedure is needed to remove a boneborne distractor, which is worse for the patient and less cost-effective. Although we did not discriminate between the two distractors, the combination of the previous studies and the absence of relapse in our combined cohort indicate that there was no difference between them in terms of stability. In our experience SARME with a toothborne distractor is adequate in most patients. In extreme cases – for example, a narrow palate with too little space for a toothborne distractor, short radices, or periodontally compromised teeth – the surgeon can choose a boneborne distractor.

The time points that we chose provide insight into the amount of relapse after activation and removal of the distractor. While most long-term studies focus on the retention phase after orthodontic treatment, our results show the amount of relapse and the time-frame when most relapses occur (mostly between T2 and T3) during the period of orthodontic treatment. This effect is probably more a result of dental decompensation during the orthodontic treatment than specific relapse of the maxillary widening. After this phase relapse was minimal, which indicated that SARME was stable in the long-term, even long after orthodontic treatment had been finished.

The increase in the width of the palate was stable, and similar to the dental width, which indicated bony expansion after SARME. Palatal depth was not significantly affected, although during the initial study there was a significant loss in the molar region using a boneborne distractor. As both groups were combined, this could not be reproduced.

Posteroanterior cephalograms were used to study the effects of SARME on bone level in both the molar and nasal basal regions but, apart from an initial increase in the molar region (T1-T3, $p = 0.046$), there was no significant effect. In theory the use of a boneborne distractor should result in more bony expansion, because the distractor applies the force cranially. In the study by Koudstaal et al they found no difference between the two distractors in maxillary tipping.[5] It seems that the maxillary tipping that occurred had no affect on the relapse of the transverse dental measurements.

With new imaging techniques being used routinely nowadays, more specific measurements can be made. Zandi et al conducted a study with the use of cone-beam computed tomography on the depth and width of the palate, nasal floor, and teeth. They confirmed our findings that the effects of SARME are more profound on the dental level and less in the nasal region.[10] They also found no significant differences with the use of a boneborne or toothborne distractor.

We have shown that SARME is a predictable technique by which to widen the maxilla, with stable long-term results on both a dental and a skeletal level. Future research on its long-term effects should incorporate 3-dimensional imaging techniques and focus on the skeletal and soft tissue effects, preferably in a randomised, controlled trial that compares both surgical techniques and distractors.

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