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Surgically-assisted rapid maxillary expansion of narrowed maxillae: a case-cohort study

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Aims: The aim of this study was to investigate a consecutive cohort of surgically-assisted rapid maxillary expansion cases to determine the indications, results and relapse associated with the procedure.
Methods: The records of 21 cases of SARME treated by the Oral and Maxillofacial Surgery and Orthodontic units at the University of Adelaide were examined. Overall expansion and subsequent relapse were compared on study models and postero-anterior cephalometric radiographs against the variables of age, gender, surgeon, surgical technique, final occlusion and the retention period. Statistical analysis was performed on paired variables.
Results: Maximum expansion was gained across the intermolar width and the most relapse identified across the canines. Male patients showed statistically greater stability across the intercanine width. There were otherwise no significant relationships between the treatment variables, stability or relapse.
Conclusions: SARME is a safe surgical technique for narrowed maxillae requiring intermolar expansion of 6 mm or more. Overexpansion of up to 60% is required to compensate for relapse.
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Introduction

Transverse maxillary hypoplasia accounts for approximately 30% of skeletal maxillofacial malformations and is a frequent anomaly in non-syndromic and syndromic patients including those with cleft palate.[1] These anomalies may be corrected, usually in adolescents but occasionally in receptive adults, through the process of rapid maxillary expansion (RME). Minor transverse discrepancies of the maxilla may be corrected without the need for surgical intervention after skeletal maturity has been reached. However, the relapse tendency of expansion treatment tends to increase with skeletal maturity as less bony displacement is likely and more dento-alveolar change occurs.[2]

Surgically-assisted rapid maxillary expansion (SARME) is a standard orthognathic procedure which is indicated for skeletally mature patients with severe transverse maxillary hypoplasia (either uni- or bilateral), anterior crowding and buccal crossbites.[1,3] This procedure provides limited dental arch space for the alignment of teeth, but also results in substantial enlargement of the maxillary apical base and palatal vault. Furthermore, it is reported to facilitate an improvement in swallowing by providing space for the tongue and offers subjective improvement in nasal breathing associated with a concomitant enlargement of the nasal chamber.[1] SARME is also indicated in young children and adolescents in whom orthodontic maxillary expansion alone is ineffective due to the extent of the changes required. Surgical intervention becomes necessary for assisting RME through distraction or overcoming the resistance at the facial sutures.[3,4]

Previous studies have shown that SARME is indicated in cases of 'large' transverse maxillary discrepancy.[1,3] The SARME surgical technique usually consists of Le Fort 1 and mid-palatal suture osteotomies with or without pterygoid plates and nasal septum releases.[1,5] Although expansion is achieved, an earlier report has indicated a significant SARME relapse of 3 – 25%.[5] Inadequacies in the expansion literature have been identified as, (1) insufficient data with regard to the degree of maxillary width deficiency and, (2) insufficient data to suggest the most appropriate surgical technique for SARME. There is also inconclusive evidence related to the stability of associated treatment variables such as pterygomaxillary disjunction (PMD) and there is little data for the indications, surgical techniques and treatment outcomes with regard to SARME procedures conducted in Australia.

The aim of the present study was to retrospectively review a patient cohort initially seen in a large public orthodontic clinic and who were identified as having a significant transverse maxillary discrepancy requiring surgically-assisted rapid maxillary expansion. The surgical indications, techniques, results and relapse tendencies were to be determined.

Methods

The cases of SARME treated by the Adelaide Oral and Maxillofacial Surgery Unit in the 5-year period of 2002 – 2007 were identified. Case notes, diagnostic models and radiographs, in particular the postero-anterior cephalometric views, for the preoperative, postoperative, post retention and final records were gathered. The protocol of management for SARME cases is presented in Table I.

Five maxillary transverse measurements were obtained; intercanine and intermolar widths from the diagnostic casts (Figure 1) and maxillary molar widths, maxillary width and nasal floor width from the postero-anterior cephalometric radiographs (Figure 2).

All measurements were taken with an electronic digital sliding caliper (0 – 150 mm) and were repeated 1 month after the initial measurements. Mean values were used to establish a master set of values from which the following was calculated: the amount of expansion (T2 – T1); the mean overall expansion (Tx – T1); the amount of relapse (T3 – T4) and the mean overall relapse (T2 – Tx), where 'Tx' was the last known value recorded for that measurement. The mean overall expansion (OE) and mean overall relapse (OR) were compared within the following variables: age, gender, surgeon, surgical technique (with respect to PMD), the final occlusion and retention period. Statistical analysis was carried out using the Student's

Table I. Cephalometric data.

Standardised protocol for each patient undergoing SARME through the OMS unit includes the following data sources and contents being accurately collected, recorded and stored by the orthodontic and the OMS units of Adelaide Dental Hospital (ADH) and Royal Adelaide Hospital (RAH).

I. Case-notes records:
   a. Demographics - age (at time of SARME procedure), gender and ethnicity
   b. Medical, dental, social and psychological histories
   c. Orthodontic data - orthodontic team, diagnosis, pre- and post- orthodontic treatment
   d. Orthognathic data - surgical team, diagnosis, date of surgery, procedural data, complications, distraction period, retention period and follow-up period
   e. All data collected to be recorded in ADH and RAH case notes and to be stored in records department of the respective hospitals.

II. Study/diagnostic model records:
   a. T1 – pre-surgical diagnostic model; during primary orthodontic and surgical survey
   b. T2 – post-surgical diagnostic model; 1 - 2 weeks after the surgery
   c. T3 – post-retention diagnostic model; retention period should be greater than 6 months
   d. T4 – follow-up diagnostic model; follow-up period should be 1 – 2 years
   e. Study models should be taken by both orthodontic and OMS units during review appointments at stages of SARME treatment, and stored in orthodontic or OMS facilities.

III. Radiographic records:
   a. Orthopantomogram (OPG) – during primary survey and at follow-up
   b. Lateral cephalometric radiograph - during primary survey and at follow-up
   c. Posterior-anterior cephalometric radiograph - at T1, T2, T3 and T4 (as for study models)
   d. All radiographic records to be trimmed to size and stored in patient case notes.

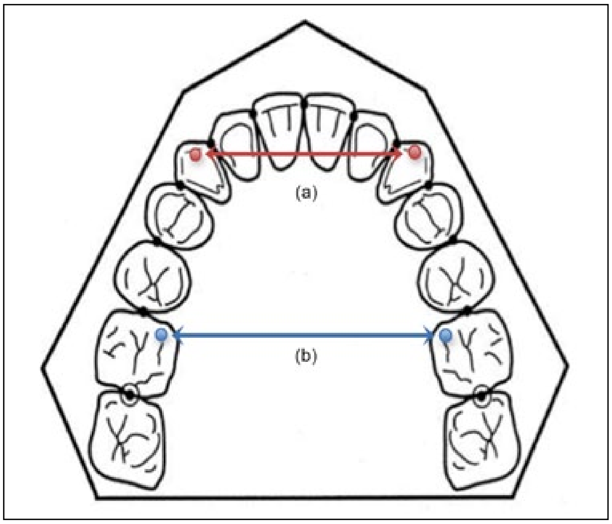

Figure 1. Study model diagram showing maxillary intercanine (a) and intermolar (b) measurement points.

t-test to determine mean differences between groups within each variable. The *p*-value was set at 0.05 with a confidence interval of 95%. All data was entered into an electronic spreadsheet using Microsoft Office Excel 2007 on a stand-alone research computer and analysed.

Royal Adelaide Hospital Research Committee approval was obtained prior to the commencement of the study (070410).

Results

Twenty-five cases were identified in the study period but 4 were managed in a private practice and the records were unobtainable and therefore discounted. The remaining 21 cases had substantial records but some deficiencies were identified in the tables. The demographics and orthodontic status of the patients is presented in Table II. None were medically compromised and all were judged to be dentally fit and exhibiting a high level of oral hygiene and dental awareness.

The surgery was principally performed by Surgeon A (15 cases, 71%) and the remaining 6 cases were operated on by two surgeons. These were grouped as Surgeons B (6, 29%). The surgical technique details are presented in Table III. All patients were treated under general anaesthesia in the Royal Adelaide Hospital and had the standard osteotomy cuts for a Le Fort 1 osteotomy with an additional mid-palatal osteotomy. In all cases, the RME device, which had been inserted

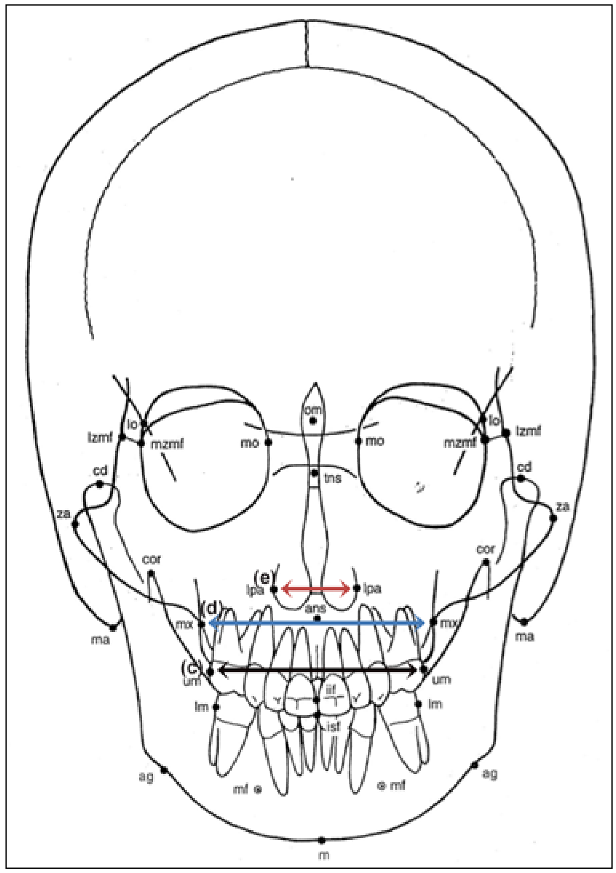

Figure 2. PA cephalometric radiograph tracing showing maxillary molar (c), maxillary (d) and nasal floor width (e) measurement points.

All measurements were taken from a CE electronic digital sliding caliper (0 – 150 mm) and were repeated after 1 month of initial measurements. Mean values were used to establish a master set of values. For each measure the following was calculated from the master set of values: amount of expansion (T2 – T1); mean overall expansion (Tx – T1); amount of relapse (T3 – T4) and mean overall relapse (T2 – Tx), where 'Tx' is the last known value recorded for that measure. Mean overall expansion (OE) and mean overall relapse (OR) were then compared within the following variables: age, gender, surgeon, surgical technique (with respect to PMD), final occlusion and retention period. Statistical analyses were carried out in the form of student's t-test to test for mean difference between groups within each variable. P-value was set at 0.05 with confidence interval of 95%.

With respect to data handling and storage, all data were collected initially in the form of data sheets. All data were entered into electronic forms of data entry (Microsoft Office Excel 2007). MS Excel 2007 program was used for all data and statistical analyses. All data will be stored for a period of 15 years in line with REC approval for this study.

preoperatively, was distracted out to its full width and then fully closed. The standard operative procedure for distraction osteogenesis was adopted to allow a 5-day latency period, followed by an expansion period requiring 1 mm per day and a subsequent retention period. Dependent on the surgeon's preference and on the expansion effect on the segments, additional surgical procedures were performed which included

Table II. Demographic and orthodontic data.

Age at surgery	19.2	± 0.5 yrs
Gender		
Female	13	(62%)
Male	8	(38%)
Ethnicity		
Caucasian	19	(91%)
Orthodontic history		
Previous failed orthodontics	4	(19%)
Class III maxillary deficiency	14	(67%)
Class II mandibular deficiency	5	(24%)
Class I	2	(9%)

Table III. Surgical techniques.

	Total	Surgeon A	Surgeon B
Le Fort I osteotomy	21 (100%)	15 (71%)	6 (29%)
Midpalatal osteotomy	21 (100%)	15 (71%)	6 (29%)
Nasal septum release	16 (76%)	15 (71%)	1 (5%)
Pterygomaxillary disjunction	9 (43%)	9 (43%)	0 (0%)
Down fracture	4 (19%)	4 (19%)	0 (0%)

either a nasal-septal release, a pterygomaxillary disjunction (PMD) or a full down fracture. No major complications from the surgery were identified.

Table IV shows the overall expansion (OE) and overall relapse (OR) for the maxillary transverse measurements, where 'N' represents the number in the sample from which the study model and radiographic measurements were collected. The mean and the range of overall expansion were greatest at the maxillary intermolar width (6.20 mm) and least at the nasal floor width (2.05 mm). The greatest relapse as a percentage of the initial expansion was seen across the maxillary intercanine width (58.19%); however, the greatest stability of treatment (least relapse) was seen across the nasal floor (25.85%).

Table V represents the groups according to each variable that presented with greater expansion of the maxilla and lower relapse of treatment (greater stability) across the maxillary transverse measurements. Males showed significantly greater SARME treatment stability at the maxillary intercanine width ($p = 0.034$), but this could be related to sample error.

Discussion

The present study revealed that a maxillary intermolar width discrepancy of approximately 6 mm and a maxillary intercanine width discrepancy of approximately 4 mm were key indicators for SARME. The less definitive indications were a maxillary molar width discrepancy of 4.5 mm, a maxillary width discrepancy of 4.5 mm and a maxillary nasal floor width discrepancy of approximately 2 mm. The variables of gender, surgeon and final occlusion did not generate significant differences in the overall expansion of the maxilla and there was no or minimal benefit to the overall expansion through the provision of a PMD or a full down fracture. Patient gender and surgeon did not show significant variation in SARME treatment stability and there was no increased stability produced by performing a PMD in patients greater than 18 years, with a Class 1 final occlusion and for a retention period greater than 6 months. These results suggested that surgeons should overcorrect the maxilla across the canines by approximately 60%, at the molars by approximately 35 – 40% and at the nasal floor by 25% of the desired arch width in order to achieve optimal arch space and stability. However, these values are individually variable. Overexpansion is biologically tolerated and allows compensation for relapse but cases with large transverse maxillary discrepancies are uncommon. The Orthodontic Clinic at the Adelaide Dental Hospital treats a minimum of 1,000 new patients per year or 5,000 over the study period. Therefore, most cases had a satisfactory outcome with orthodontic treatment alone, with only 0.004% requiring surgical maxillary expansion. Similarly, the Oral and Maxillofacial Surgical Unit of the Royal Adelaide Hospital performs a minimum of 70 new orthognathic cases a year or 350 over the study period. Of these, only 21 (0.8%) required a SARME procedure. A discussion of SARME procedures occurred at the ANZAOMS National meeting in 2010 at which it was evident that the present study represents the largest series of SARME cases in Australasia.

The main concern of the present study was that some records were incomplete. This was despite a diligent search of both the OMS and Orthodontic Unit records and likely reflects the variable interest and

Table IV. Expansion gained and overall relapse at the measured points.

Maxillary transverse measurement	Overall expansion				Overall relapse		
	N	Mean (mm)	SD/Variance (mm)	Range (mm)	N	Mean (mm)	Range (mm)
Maxillary intercanine width	10	3.97	1.91 / 3.66	5.93	7	2.31 (58.19%)	6.82
Maxillary intermolar width	10	6.20	2.24 / 7.51	7.97	7	2.36 (38.06%)	5.84
Maxillary molar width	16	4.42	2.09 / 4.36	6.61	6	1.47 (33.36%)	3.28
Maxillary width	16	4.31	1.86 / 3.46	5.79	6	1.65 (38.28%)	2.13
Nasal floor width	16	2.05	1.12 / 1.26	3.91	6	0.53 (25.85%)	1.03

Table IV. Comparison of paired variables.

Variables / N		Maxillary intercanine	Maxillary intermolar	Maxillary molar width	Maxillary width	Nasal floor width
Age						
> 18 – 10	Greater OE	> 18	> 18	< 18	> 18	> 18
< 18 - 11	Lower OR	< 18	> 18	< 18	< 18	< 18
Gender						
Male – 8	Greater OE	Male	Female	Male	Male	Female
Female - 13	Lower OR	Male*	Male	Male	Female	Male
Surgeon						
Surgeon A – 15	Greater OE	Surgeon A	Surgeon A	Surgeon A	Surgeon A	Surgeon O
Surgeon O – 6	Lower OR	Surgeon A	Surgeon A	Surgeon O	Surgeon O	Surgeon O
Technique						
PMD – 9	Greater OE	PMD	nPMD	nPMD	PMD	PMD
nPMD – 12	Lower OR	nPMD	nPMD	PMD	PMD	PMD
Final occlusion						
Class 1 – 11	Greater OE	Class 1	X-bite	X-bite	Class 1	X-bite
X-bite - 5	Lower OR	Class 1	Class 1	Class 1	Class 1	Class 1
Retention period						
> 6 months - 7	Greater OE	> 6 months	< 6 months	< 6 months	> 6 months	> 6 months
< 6 months - 9	Lower OR	< 6 months	< 6 months	< 6 months	< 6 months	< 6 months

* = signifcant difference ($p < 0.05$); otherwise no significant difference

understanding, in ensuring that post operative records were completed once the patient recovered from the surgical procedure.

The findings concerning maxillary width discrepancy are in agreement with Wertz,[6] Haas,[7] Bishara and Stanley[8,4] and Betts et al.,[8] who considered that the indications for SARME included posterior skeletal crossbites exceeding 5 mm. Silverstein and Quinn[3] also indicated that SARME primarily be used in patients who possessed a transverse maxillary deficiency of more than 5 mm and whose age was greater than 15 years. Kaudstaal et al.[1] stated that 'once skeletal maturity had been reached, orthodontic treatment alone could not provide a stable widening of the constricted maxilla in cases of deficiencies of more than 5 mm,' and provided a distraction range of 3.4 – 8.0 mm in the first molar region for SARME. However, in a study of transverse maxillary distraction by Ramiera et al.,[9] the mean amount of expansion was determined to be 3.22 mm. Similarly, Sokucu et al.[10] showed a mean increase in transverse intermolar distance of 2.87 mm for SARME. These results are not consistent with those of the present study, which found larger expansion values across the maxillary intermolar distance. Individuals display considerable variation in maxillary transverse width, which may be related to age, gender, ethnicity and/or surgical technique.[11] The extent of transverse constriction of the maxilla can also vary in accordance with the width of the mandible, the perception of uni/bilateral crossbites and also the references used for maxillary arch width measurement.[11]

The expansion of the maxilla with PMD showed findings that were consistent with those of Kennedy et al.,[13] Lines[14] and Bell and Jacobs,[15] who found that uniform palatal expansion can be achieved in either non-extraction or extraction cases without sectioning of the palate or the pterygoid plates. However, reports by Kaudstaal et al.[1] showed that the pterygoid plates were a considerable site of resistance for maxillary transverse expansion. Similarly, Swennen et al.[5] concluded that the nasomaxillary suture complex was increasingly compromised, depending on the number of osteotomy sites, most of which were influenced by the pterygomaxillary suture. Upon release of the maxilla from the pterygoid plates, a greater amount of lateral movement of the maxillae was possible and therefore greater expansion. However, due to the increased risk of injuring the pterygoid venous plexus as a result of an osteotomy in the region, surgeons tend to avoid release of the pterygoid plates.

Post-surgical relapse changes following PMD were similar to those described by Magnusson et al.,[16] who showed that pterygoid detachment did not entirely eliminate posterior resistance which therefore facilitated relapse seen as the buccal tipping of the maxillary molar teeth. Anttila et al.[17] differed and described and supported PMD as an important factor affecting the stability and relapse of SARME and the long term stability of maxillary expansion.

The patients in the present study were older than the recommended age of 13-15 for RME and SARME.[1,4] A relationship between age and relapse was not identified in the literature and the present findings were in conflict with the premise that individuals under the age of 18 years had greater stability of treatment.[1,6] It was suggested that young individuals were more likely to adapt in response to the surgical distraction forces and were also more likely to obtain a bony union at the osteotomy site.

Wertz[6] showed that SARME procedures carried out in non-growing individuals exhibited significantly lower relapse compared with RME cases. Koudstaal et al.[1] reported, in a long-term evaluation of SARME procedures, that the age of the patient played a vital role in the stability of treatment, as younger patients showed greater post-surgical stability. The final occlusion was considered an important factor that affected the stability and relapse of SARME treatment. It was believed that the maxillary arch width in an Angle's Class I occlusion was 'contained' by the mandibular arch, whereas a crossbite relationship was not, and therefore more likely to relapse.[18] The findings from the present study differed from those of Proffit,[18] who recommended treating to a Class 1 final occlusion following orthognathic procedures in order to enhance stability.

The current findings regarding the retention period are not well supported although Stromberg and Holm[19] conducted a similar retrospective SARME study and found that there was no difference between the length of the retention period and subsequent relapse, although statistical significance was overlooked.[19] The findings of Northway and Meade,[20] Sokucu et al.[10] and Byloff and Mossaz[21] were contrary to those of the present study. Byloff and Mossaz[21] found that during the 1-year post retention period, an arch width reduction of 2.62 mm occurred across the molar region, which equated to 30% of the initial expansion. However, this was not recorded to be of statistical significance. Sokucu et al.[10] also drew conclusions in support of Northway and Meade,[20] who compared RME and SARME and reported no significant changes in the intercanine and intermolar widths 1-year post retention.[18,23]

SARME research has reported significant treatment relapse,[5,12,20,22,23] which suggests the need for overcorrection of maxillary expansion. However Pogrel et al.[24] and Bays and Greco[25] used tooth-borne devices for expansion and reported that SARME had excellent stability and did not require overcorrection. In addition, it was stated that bone-borne distraction required no overexpansion as no relapse was claimed.[21,26] Byloff and Mossaz[21] recommended overcorrection of the initial maxillary width discrepancy in order to compensate for the relapse of treatment. This was first described by Haas in the 1960s,[7] who pioneered the need for overcorrection (hypercorrection) of a transverse discrepancy in the maxilla. The findings from Byloff and Mossaz[21] and Haas[7] support the findings of the current study, which recommended overcorrection of the maxilla during the expansion process in order to compensate for overall relapse.

Conclusions

The present study concluded that maxillary intermolar, intercanine, maxillary molar, maxillary and nasal floor width discrepancies requiring SARME management were approximately 6 mm, 4 mm, 4.5 mm, 4.5 mm and 2 mm respectively. The variation in maxillary transverse width related to age, gender, ethnicity and/or surgical technique[11] suggested that these maxillary width factors should be used only as a guide to determine the need for SARME. The study further concluded that PMD and patients older than 18 years did not create a greater need for expansion of the maxillary arch. In addition, PMD, older patients, a Class 1 final occlusion and a retention period greater than 6 months did not result in greater stability of SARME treatment. Overexpansion of the maxilla was required across the canines, molars and nasal floor by 60%, 35 – 40% and 25% respectively, to account for the expected relapse of SARME treatment.

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Conflict of Interest

None declared.

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