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Three-dimensional effects of pterygomaxillary disconnection during surgically assisted rapid palatal expansion: a cadaveric study

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Objective. The aim of this study was to investigate the influence of pterygomaxillary disconnection on the transversal expansion of the maxilla.

Study Design. Fifteen cadaver heads were used for surgically assisted rapid palatal expansion (SARPE), which was carried out twice on the same heads—with and without pterygoid disconnection. The maxillae were expanded by 10 mm by using a rapid palatal expander. Study models before and after both SARPE techniques were made and scanned by an oral scanner for virtual analysis by software.

Results. Performing pterygomaxillary disconnection during SARPE led to a decrease in the deviation between the incisor regions from 5.42 ± 1.13 mm to 4.05 ± 1.12 mm ($P = .002$) and an increase in the distance between second premolar regions from 2.63 ± 1.64 mm to 4.07 ± 2.01 mm ($P = .040$).

Conclusions. SARPE without pterygomaxillary disconnection led to a V-shaped transverse expansion of the maxilla, whereas osteotomy of the pterygoid plates led to a parallel transverse expansion. (Oral Surg Oral Med Oral Pathol Oral Radiol 2016;121:602-608)

Transverse maxillary constriction is one of the most common malocclusions, which is characterized by typical clinical manifestations of maxillary compression, such as dental crossbite and crowding of teeth. Angell first described the rapid maxillary expansion procedure for the treatment of transverse maxillary discrepancy in 1860.[1] Orthopedic forces applied on an expander lead to the opening of the midpalatal suture, thereby allowing the maxilla to widen.[2] Although this method is well established, it has limitations in adult patients, such as increased bone thickness, decreased bone elasticity, and fusion of the maxillary sutures during skeletal maturation. Attempting to expand the maxilla orthopedically at this stage will result in relapse of the transverse discrepancy upon removal of the expander.[3] Surgically assisted rapid palatal expansion (SARPE) allows for resolving the skeletal discrepancy without undesirable side effects, such as lateral tipping of the posterior teeth, buccal fenestrations, failure to open the midpalatal suture, bending of the alveolar process, extrusion of the posterior teeth, pain, instability, and root resorption.[4]

Several techniques and osteotomy designs have been described for the SARPE of the maxilla. However, there is no consensus on the best surgical procedure, and the preference of the surgeon often determines the choice. At present, the zygomatic buttress and pterygomaxillary junction are the most rigid bony pillars of resistance.[5] Although some authors advocate disconnection of almost all the articulating maxillary structures to allow for sufficient transversal expansion,[6-8] others support SARPE without pterygomaxillary disconnection to achieve the lowest possible levels of postoperative complications and morbidity.[9-13] Koudstaal et al. reported that performing SARPE without pterygoid separation resulted in a different pattern of expansion.[14] In their opinion, the ratio of anterior expansion to posterior expansion is higher in patients without pterygomaxillary disconnection than in those receiving osteotomy for disarticulation of the pterygoid plates. They concluded that this fact should be considered while planning the surgical treatment for skeletal malocclusions in patients. A cone beam computed tomography study by Sygouros et al. focused on both

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Statement of Clinical Relevance

A V-shaped transverse expansion of the maxilla can be achieved by surgically assisted rapid maxillary expansion without pterygomaxillary disconnection, whereas for a parallel transverse expansion, the pterygomaxillary disconnection seems to be necessary.

surgical techniques and found no significant differences between SARPE with pterygomaxillary disconnection and SARPE without pterygomaxillary disconnection.[15] However, the patient group without pterygomaxillary disconnection had a more pronounced buccal bending of the alveolar process and an increased buccal tipping of the posterior teeth, although this was not statistically significant. They concluded that pterygomaxillary disconnection could be advised for periodontally compromised patients. Similar results were reported by Kilic et al. who investigated study models in both SARPE groups and found no significant differences after maxillary expansion. However, they noted a tendency for greater posterior expansion in patients with pterygomaxillary disconnection.[16] However, Seeberger et al. reported a tendency toward a V-shaped morphology of the lower nasal airway and a similar V-shaped pattern in the width of the palatal arch, even when disconnection of the pterygoid plates was performed.[17] Although most current studies have reported on the clinical effects of SARPE, there is still no consensus on the effects of pterygoid plate disconnection in this procedure. In this cadaveric study, we aimed to perform a three-dimensional evaluation, compare the dentoskeletal changes brought about by SARPE with and without osteotomy of the pterygoid plates, and observe whether the pterygomaxillary disconnection led to a greater posterior expansion of the posterior segment of the maxilla.

MATERIALS AND METHODS

After institutional approval, 15 thiel-embalmed human cadaver heads of seven females and eight males, with a mean age of 66.5 years (range 54−78 years), were used to perform SARPE, which was conducted twice on the same cadaver head with and without pterygomaxillary disconnection. All surgical procedures were performed by the same surgeon, following the Declaration of Helsinki.

In the first technique, an incision was made from the region of the first molar to the midline on both sides of the maxillary vestibule. A subperiosteal soft tissue reflection from the lateral wall of the maxilla was then performed, thus exposing the anterior floor of the nose and the piriform aperture area posteriorly up to the pterygomaxillary fissure. Osteotomy was performed from the piriform aperture through the zygomatic buttress up to the pterygomaxillary junction. A periosteal elevator was used to lift the nasal mucoperiosteum to protect the nasal mucosa. The nasal septum was released with a septum osteotome, followed by malleting with a thin Lambotte osteotome on the lateral left of the midpalatal suture (Figure 1). Subsequently, a mechanical expansion was performed with a rapid palatal expander (RPE) (51-565-18-09, KLS Martin, Tuttlingen, Germany). The RPE distractor, which is an established device for bone-borne palatal expansion, was turned until bony resistance was first encountered, followed by 10 more turns, resulting in a 10-mm expansion. The expansion was gradually performed to allow adaptation of the bone to reduce the risk of fractures. Maxillary width and form were recorded by taking impressions of the maxilla by using Impregum Penta (3 M ESPE, Neuss, Germany) before and after both SARPE procedures. This polyether impression material exhibits a high level of accuracy, dimensional stability, reliability, and precision in recording anatomic details.[18] Undercuts below the expander were blocked with plasticine before taking impressions. The distractor was then turned back to reduce any stress exerted on the jaw during subsequent procedures and allow similar starting conditions of the second distractor mobilization.

Fig. 1. Detachment of the pillars of the maxilla with osteotomies between the piriform apertures, through the zygomatic buttress, to the maxillopterygoid junction, the nasal septum, and lateral to the midpalatal suture, and without pterygomaxillary disconnection (group 1).

In the second technique, pterygomaxillary disconnection was performed by placing a curved pterygoid chisel between the tuberosity and the pterygoid plates, followed by turning the RPE 10 times again and taking impressions of the maxilla. All impressions were poured with super-hard plaster (Alpenrock, Amann Girrbach, Koblach, Austria) (Figure 2). The models were transferred to virtual reality by using digital scans with a Lava Chairside Oral Scanner (3 M ESPE, Seefeld, Germany). Each patient had three stereolithographic files, which were imported into the Geomagic Qualify software (Geomagic, Morrisville, NC, USA). The preoperative and postoperative conditions were compared by using automatic surface registration of the virtual models on the basis of an iterative closest point algorithm. The virtual model of the upper jaw preoperatively acted as the reference model, and the two virtual models after SARPE were

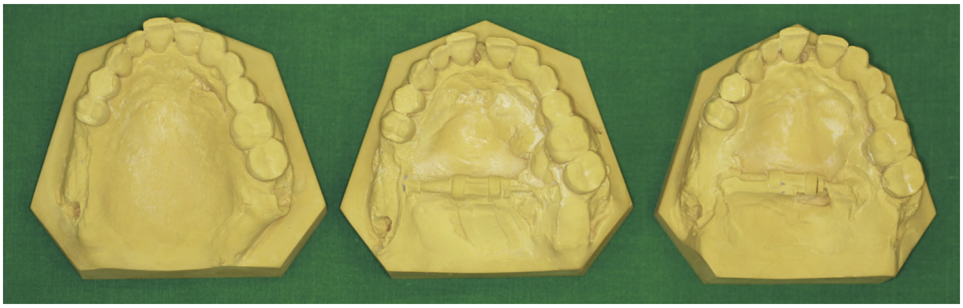

Fig. 2. Situation models before (left) and after rapid maxillary expansions with the rapid palatal expander (RPE) about 10 turns/10 mm without (middle) and with pterygomaxillary disconnection (right).

considered to be the test models. The RPE and the plasticine were cut out of the virtual models before comparison to reduce interference. The deviations in the surfaces of the test and reference objects were measured by using Geomagic Qualify software. The plicae palatinae transversae and incisive papilla of the anterior soft tissue of the palate were used as references for comparison. The measured deviation indicates the shortest distance from the object, set as "test," to any point on the object, set as "reference." This completely automated process generates a full-color deviation map and a histogram comparing the two surfaces. The color map overlay shows the proximity of objects with green, whereas red represents increased differences in distance from the virtual simulation (Figure 3). The sagittal plane that passes through the incisive papilla was set as the border between the right and left palates. In the transversal dimension, the distance between the alveolar ridge regions of the central incisors and the second premolars was calculated. In the vertical dimension, the maximum changes in the right and left parts of the overall palate were measured.

Statistical analysis

All statistical analyses were performed by using the Statistical Package for Social Sciences (SPSS) version 23 (SPSS Inc., Chicago, IL) on Apple OS X v10.10.2 (Apple Inc., Cupertino, CA). Shapiro−Wilk normality test and Levene's variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance among the groups. The Student's t test was used, and the level of significance was set at $P \leq .05$. All results are expressed as mean ± standard deviation (SD).

RESULTS

The mean linear distances between the regions of the maxillary incisors as well as between the regions of the second premolars before and after SARPE with and without pterygomaxillary disconnection are shown in Table I. The differences in the maximum deviation between the virtual models after both SARPE techniques are presented in Table II. The boxplot diagram (Figure 4) shows the comparison of the mean values of deviation after SARPE with and without pterygomaxillary disconnection and the corresponding P values.

In the transversal dimension, pterygomaxillary disconnection during SARPE decreased the maximum deviation between the incisor regions from 5.42 ± 1.13 mm to 4.05 ± 1.12 mm, which was statistically significant (P = .002). An increase was also observed in the premolars from 2.63 ± 1.64 mm to 4.07 ± 2.01 mm (P = .040), which was also statistically significant.

In the vertical dimension, no differences were observed in the palate after both techniques. On the right side, the mean values were −0.46 ± 0.22 mm in the group without pterygomaxillary disconnection and −0.47 ± 0.22 mm in the group with pterygomaxillary disconnection. On the left side, the group without pterygomaxillary disconnection showed a mean value of 0.92 ± 0.19 mm, whereas the group with pterygomaxillary disconnection showed a mean value of 0.93 ± 0.43 mm.

DISCUSSION

Different locations of bony resistance to maxillary expansion have been described in the context of SARPE, which include the anterior piriform aperture pillars, lateral zygomatic buttresses, posterior pterygoid junctions, and medial midpalatal synostosed sutures.[4] Although SARPE is a well-established technique for the correction of transverse maxillary discrepancies, there is no consensus on the ideal surgical technique and the type of distraction device (tooth-borne or bone-borne) because of the inadequate evidence on the corresponding skeletal effects.[17] Betts and Ziccardi observed weakening of the anterior, lateral, posterior, and median supports of the maxillary arch by a total bilateral maxillary osteotomy, from the piriform

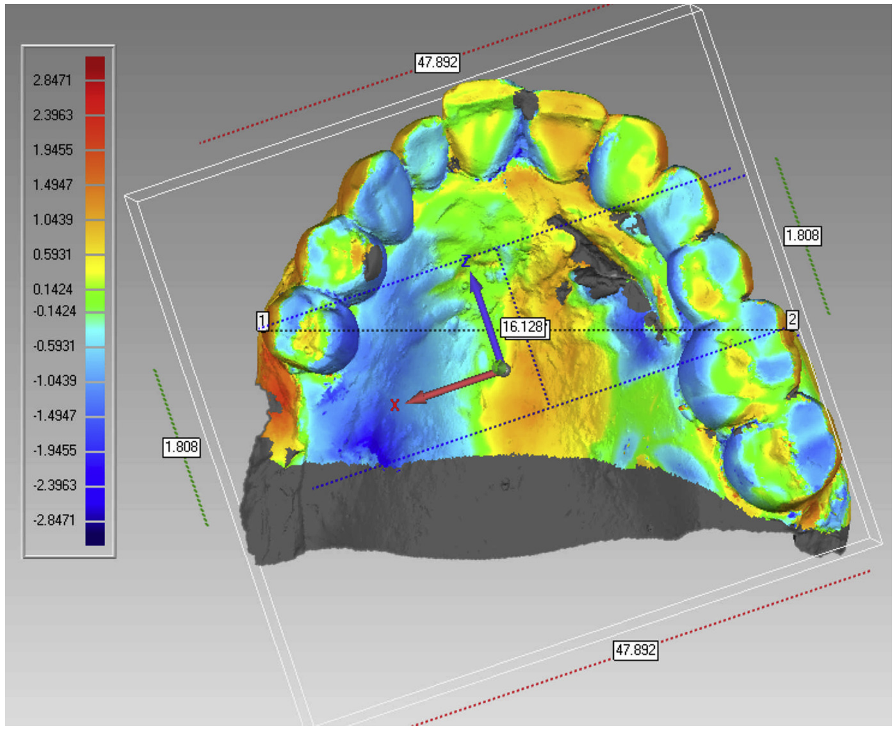

Fig. 3. Software based comparison of the virtual models before and after surgery with pterygomaxillary disconnection using an iterative closest point algorithm.

Table I. Mean linear distances between the regions of the maxillary incisors and the regions of the second premolars before and after surgically assisted rapid palatal expansion (SARPE) with and without pterygomaxillary disconnection

	Region–distances (mm)					
			After SARPE			
	Before SARPE		*Without pterygomaxillary disconnection*		*With pterygomaxillary disconnection*	
Cadaver	*Incisor*	*Second premolar*	*Incisor*	*Second premolar*	*Incisor*	*Second premolar*
1	4.51	40.51	9.63	42.12	7.43	44.51
2	1.32	46.53	7.76	50.49	6.31	53.30
3	1.19	46.46	6.31	47.51	5.56	49.49
4	2.52	51.23	7.62	53.42	5.79	54.23
5	1.11	48.53	6.29	50.23	5.92	52.34
6	2.16	46.51	6.60	52.53	4.55	53.53
7	1.04	41.19	4.91	43.21	4.91	43.27
8	0.00	49.11	6.97	51.58	6.78	53.49
9	1.79	44.49	6.18	44.53	6.21	44.54
10	1.01	49.29	7.88	53.55	5.34	54.81
11	0.09	49.09	7.33	51.23	4.43	53.86
12	1.78	44.01	6.32	46.32	4.91	46.31
13	0.00	48.18	6.19	53.64	4.62	55.56
14	1.88	44.05	7.84	46.87	5.88	48.22
15	1.60	47.55	5.44	48.92	4.11	50.32
Mean	1.47	46.45	6.88	49.08	5.52	50.52
SD	1.14	3.07	1.17	3.82	0.94	4.19

SD, Standard deviation.

aperture to the pterygomaxillary fissure, with a midpalatal split and an additional release of the nasal septum and pterygoid plates.[19] However, Lehman et al. renounced the pterygomaxillary disconnection and considered an osteotomy of the zygomatic buttress to be sufficient to overcome the skeletal

Table II. Mean differences in maximum deviation between virtual models after both surgically assisted rapid palatal expansion (SARPE) techniques

	Deviation after SARPE (mm)							
	Without pterygomaxillary disconnection				*With pterygomaxillary disconnection*			
Cadaver	*Incisor*	*Second premolar*	*Palate right*	*Palate left*	*Incisor*	*Second premolar*	*Palate right*	*Palate left*
1	5.12	1.61	−0.24	0.5	2.92	4	−0.28	0.52
2	6.44	3.96	−0.67	1.34	4.99	6.77	−0.66	1.32
3	5.12	1.05	−0.27	0.53	4.37	3.03	−0.25	0.49
4	5.1	2.19	−0.42	0.83	3.27	3	−0.45	0.89
5	5.18	1.7	−0.34	0.68	4.81	3.81	−0.33	0.66
6	4.44	6.02	−0.8	1.6	2.39	7.02	−0.82	1.64
7	3.87	2.02	−0.43	0.86	3.85	2.14	−0.41	0.81
8	6.97	2.47	−0.41	0.81	6.78	4.38	−0.45	0.89
9	4.39	0.04	−0.01	0.01	4.42	0.05	−0.06	0.12
10	6.87	4.26	−0.74	1.51	4.33	5.52	−0.76	1.46
11	7.24	2.14	−0.41	0.81	4.34	4.77	−0.44	0.87
12	4.54	2.31	−0.52	1.04	3.13	2.3	−0.49	0.98
13	6.19	5.46	−0.73	1.46	4.62	7.38	−0.77	1.53
14	5.96	2.82	−0.6	1.18	4	4.17	−0.55	1.12
15	3.84	1.37	−0.32	0.63	2.51	2.77	−0.29	0.58
Mean	5.42	2.63	−0.46	0.92	4.05	4.07	−0.47	0.93
SD	1.13	1.64	0.22	0.19	1.12	2.01	0.22	0.43

SD, Standard deviation.

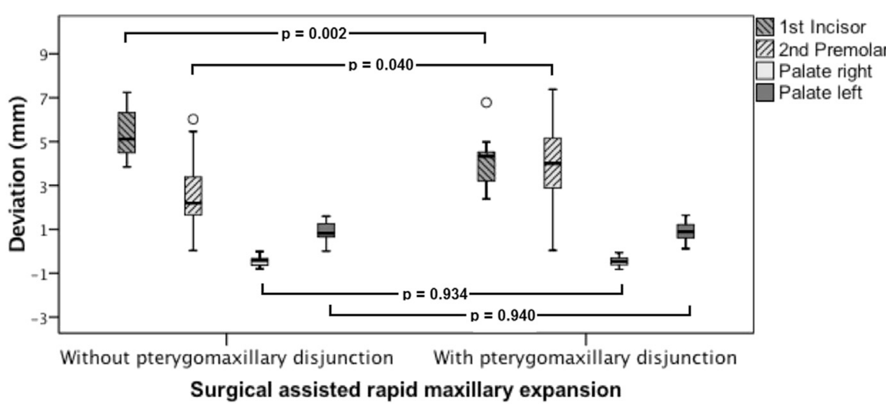

Fig. 4. Boxplot of the comparisons between the deviations after surgically assisted rapid palatal expansion (SARPE) with and without pterygomaxillary disconnection.

resistance to maxillary expansion.[20] Furthermore, some authors have reported an increased risk of palate fracture because of the extreme forces caused by the invasion of the pterygomaxillary junction.[12,21] Pogrel et al. recommended only a single midpalatal osteotomy and an additional weakening of the lateral maxillary buttress.[22] Sygouros et al. recently compared the skeletal, dentoalveolar, dental, and periodontal changes in 20 patients after performing SARPE with and without pterygomaxillary disconnection.[15] After both surgical procedures, they found a transverse and dentoalveolar increase in the transverse distances in the maxilla. However, a more pronounced bending of the dentoalveolar unit and tipping of the posterior maxillary teeth toward the buccal side were observed in the absence of osteotomy of pterygoid plates. They concluded that irrespective of whether or not pterygomaxillary disconnection is performed, SARPE is an effective technique for the treatment of transverse maxillary discrepancies. Nevertheless, the periodontal support is compromised when disconnection of the pterygoid plates is not performed. Moreover, Kilic et al. compared the dental and skeletal differences between patients who underwent SARPE with and without pterygomaxillary disconnection by retrospectively investigating orthodontic models.[16] Along with the width of the maxillary dental arch, the height of the clinical crown, the first molar axial angulation, and the palatal vault angle were also analyzed. They found an increase in the transverse maxillary distances after both expansion techniques. Although no statistically significant differences were observed between both SARPE groups, a greater transverse expansion was detected at the midpalatal and gingival levels in patients without pterygomaxillary disconnection. In contrast, SARPE combined with pterygomaxillary disconnection led to a slightly greater increase in the transverse distance at the apical base level, less tipping of the molar teeth, and even a slight increase in the transverse expansion in the molar region. Furthermore, no changes in the clinical crown height were observed after both techniques.

In the present cadaveric study, we investigated the influence of pterygomaxillary disconnection during SARPE. Using fresh human cadavers, we compared the two surgical procedures for transverse maxillary expansion directly after performing the osteotomy. It has to be mentioned that issues such as the one analyzed in our study could only be checked in a cadaveric study because performing different techniques for SARPE on the same patient is not possible with living patients. Another advantage is that the outcomes can be compared simultaneously and directly, which cannot be done in clinical practice. However, expansion of the maxilla by 10 mm without pterygomaxillary disconnection may weaken the junction. Subsequently, the use of an expander device, even without separation, may result in greater symmetric expansion of the posterior maxilla. Therefore, all the improvements in the posterior expansion cannot be entirely attributed to the technique of pterygomaxillary disconnection when an expander with osteotomies was previously used in the site.

In contrast to most previous studies, we found statistically significant changes among patients receiving SARPE with or without pterygomaxillary disconnection. This can probably be attributed to our study design, which allows for comparison of both surgical procedures on the same individual, which is impossible with in vivo studies. Only in one cadaver with a pterygomaxillary junction, an expansion of less than 1mm improvement in the posterior maxillary expansion was found. This may have resulted from insufficient disjunction of the pterygoid plates. It also appears that such studies require, in contrast to this investigation, larger sample sizes to achieve significant results. Kilic et al. retrospectively investigated study casts of 18 patients who were divided into two groups (10 patients without and 8 patients with pterygomaxillary disconnection); the study by Sygouros et al. was based on 10 patients in each group. In both studies no significant differences between the groups were found. However, we should take into consideration the possibility that the different skeletal effects may modify over time because of continuous bone remodeling during the treatment process. Although our study design allowed the maximum transverse expansion of the maxilla immediately after performing SARPE, expansion may take a few weeks during actual clinical treatment, depending on the treatment goals.

Consistent with the study by Seeberger et al.,[17] our results demonstrated that a V-shaped transverse shift of maxillary bone segments could be expected while performing SARPE without osteotomy of the pterygoid plates. We also found that SARPE with pterygomaxillary disconnection resulted in a parallel shift of the anterior and posterior segments of the maxilla. Moreover, vertical changes between both sides of the hard palate were noted, but there was no difference between the two SARPE procedures. This difference can probably be explained by the osteotomy design, which was performed lateral and left to the midpalatal suture. Several clinical changes of the palatal arch brought about by SARPE may be related to the anatomic differences in the areas of bony resistance. Additional studies are warranted to examine how an osteotomy that is conducted directly through the palatal suture can affect the hard palate. If equal and balanced changes are observed, central midpalatal osteotomy should be given preference. Furthermore, the transverse maxillary expansion did not match the mechanical expansion, which was performed with the RPE. We assume that bony resistance is also responsible for this phenomenon. Therefore, the suggestion of weakening of almost all of the articulating maxillary structures[6-8] seems legitimate.

CONCLUSIONS

In spite of the limitations of this study, we conclude that SARPE is an effective method to achieve transverse maxillary expansion. SARPE performed without osteotomy of the pterygoid plates leads to a V-shaped transverse expansion, whereas SARPE with pterygomaxillary disconnection shows a parallel transverse maxillary expansion in the anterior and posterior segments of the maxilla. However, mechanical transverse expansion does not match clinical expansion, possibly because of bony resistance.

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