Stability of surgically assisted rapid palatal expansion with and without retention analyzed by 3-dimensional imaging

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Introduction: Surgically assisted rapid palatal expansion (SARPE) is the procedure of choice for treatment of adults with transverse maxillary deficiency greater than 7 mm. There is no consensus about the dentoskeletal effect of an orthodontic retainer on the outcome of SARPE. Our objective was to assess the effectiveness of an orthodontic retainer on dentoskeletal stability. **Methods:** Ninety digitized dental casts of 30 adults undergoing SARPE were divided into 2 groups—no retention (n = 15) and retention (n = 15)—and assessed. The dental casts were obtained at 3 checkpoints: (1) 7 days on average before SARPE (preoperatively), (2) 4 months after expansion, and (3) 10 months after expansion was completed. The retention patients received a transpalatal arch just after expander removal, at checkpoint 2. The transpalatal arch was kept for 10 months after completion of the expansion (checkpoint 3 and end of the study). The dental casts were scanned with a Vivid 9i 3D laser scanner (Konica Minolta, Wayne, NJ). The distances measured were premolar and molar intercusp distances, premolar and molar intercervical distances, premolar and molar inter-WALA (Will Andrews and Lawrence Andrews) ridge distances, and palate height at the maxillary first molar. **Results:** The planned maxillary expansion was within the expected amount ($P < 0.05$). Palatal height at the 4-month checkpoint decreased by 0.79 mm (4.38%) ($P < 0.001$) and again at the 10-month checkpoint by 0.38 mm (0.98%) ($P > 0.05$) but not significantly in both groups. The premolar intercusp distance had a relapse at checkpoint 3 of 1.84 mm (7.18%) ($P < 0.001$) in the no-retention group. Both groups had average relapses of 0.95 mm in the premolar intercervical distances, of 0.88 mm in the premolar inter-WALA ridge distances, of 1.04 mm in the molar intercusp distances, of 0.74 mm in the molar intercervical distances, and of 0.84 mm in the molar inter-WALA ridge distances ($P < 0.05$) at checkpoint 3. **Conclusions:** The analysis of relapse in both groups suggests that the use of a transpalatal arch as a retaining device does not improve dento-osseous stability. (Am J Orthod Dentofacial Orthop 2014;145:610-6)

Surgically assisted rapid palatal expansion (SARPE) is the treatment of choice to correct transverse maxillary deficiencies greater than 7 mm in skeletally mature patients. SARPE is an orthopedic procedure in which areas resisting expansion are surgically released by osteotomy, and an expander is activated after surgery until the desired amount of expansion is achieved.[1]

The surgical results are thought to be maintained using fixed or removable retainers, which would ensure the dimensional stability of SARPE.[2] To date, there is no consensus regarding the time allowed for effective bone healing before removing the expansion device, the time to begin orthodontic treatment, and the effectiveness of a transpalatal arch (orthodontic retainer) to guarantee the skeletal expansion with SARPE.[3-6]

The outcome of SARPE can be assessed indirectly by studying radiographs or tomographs, or directly by analyzing dental casts. Radiographs are not expensive, but superimpositions of cranial bone structures and dental units compromise precise measurements. Tomographic imaging provides a much better visualization

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but involves high costs and might not be readily available in some countries. Using plaster models to assess the outcome of maxillary dental arch expansion combines low cost, simplicity, and accuracy. Recent advances in technology and computer science have made the accurate digitization of objects available. This enhances the dimensional assessment of dental casts and, most importantly, saves the space formerly used to store models.[7-13]

Object digitization by laser scanning is simple and fast. Studies have shown that this technology produces measurements that are as reliable as those taken directly on the dental models.[7,9] Therefore, in this study, we aimed to assess the effectiveness of an orthodontic retainer as a means of guaranteeing dentoskeletal stability after SARPE.

MATERIAL AND METHODS

This research was approved by the research ethics committee of the Federal University of São Paulo in Brazil (clinical trials number, NCT01770782; #0949/09). All participants signed an informed consent form.

After sample size calculation, the images of 90 digitized plaster casts from 30 patients who had SARPE at the Cranio-maxillofacial Surgery Outpatient Clinic of the Division of Plastic Surgery were assessed.

Based on a 5-participant sample from the 2 treatment groups and the 2 main measurements of interest—the molar and premolar WALA (Will Andrews and Lawrence Andrews) ridge distance—the relapse variation was less than 0.5 mm in both groups (SD, <0.5 mm). Assuming that the nondifference in relapse between the participants who used or did not use retainers was not greater than 1 mm, with 80% power and a 95% confidence interval, we calculated the number of participants at 4 per group. Nevertheless, to detect even smaller differences in relapse between the 2 groups, 15 participants were included in each group.

Adults with a bilateral crossbite and a transverse maxillary deficiency greater than 5 mm were included in the study. Patients with previous maxillary surgery, congenital craniofacial deformities, or a unilateral transverse maxillary deficiency were excluded.

The sample was randomized with 10-patient blocks in 2 groups. The group without retention comprised 15 patients—8 men (53.3%), 7 women (46.7%); average age, 26.3 years (SD, 5.3 years)—and none was prescribed any type of retention after removal of the expander. The group with retention also comprised 15 patients—10 men (66.7%), 5 women (33.3%); average age, 25.3 years (SD, 6.0 years)—and they received transpalatal arch fixed retainers.

On average, approximately 1 week before surgery, the same orthodontist (G.P.R.P.) placed modified hyrax-like devices (A2620-12; Leone, Florence, Italy) in all participants. The devices were made by the same laboratory technician. Initial plaster casting was performed before expander cementation (preoperatively) using type IV plaster.

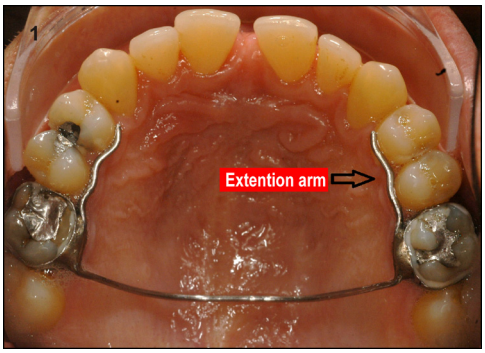

Fig 1. Transpalatal arch and extension arm.

Surgery was performed in all 30 participants by the same surgeon (M.D.P.), who used the subtotal LeFort I technique, with separation of the pterygomaxillary fissure.[1] The operation was performed under general anesthesia with orotracheal intubation. After the osteotomies, the expander screw was activated to 1.6 mm intraoperatively until a small diastema was observed between the maxillary central incisors. The incision was sutured in 2 layers.

On postoperative day 4, the expander screw activation protocol was initiated, rotating a quarter turn (0.2 mm) twice per day. After achieving the intended expansion of the maxilla width, the expansion screw was blocked, and the hyrax appliance was left in place for 4 months.

After this 4-month period, the hyrax appliance was removed, and a second plaster casting was performed for all patients. Whereas the patients in the retention group received a transpalatal arch (Fig 1) for orthodontic retention, those in the no-retention group received no orthodontic device.

The transpalatal arches in the retention patients were made with a 1.2-mm-diameter stainless steel wire and had welded bands for fixation onto the maxillary first molars. The transpalatal arch's extension arms reached the first premolars. Both groups resumed their routine activities for 6 months. Then they were contacted to have the transpalatal arches removed (retention patients) and to have a third plaster model cast (all patients).

The digitized plaster casts captured by a surface laser scanner (Vivid 9i; Minolta, Wayne, NJ) connected to a computer (Vaio model PCG-81311X; Sony, Tokyo, Japan) were stored for reading and elaboration of a polygon representing a virtual copy of the original plaster cast; this procedure was performed using software

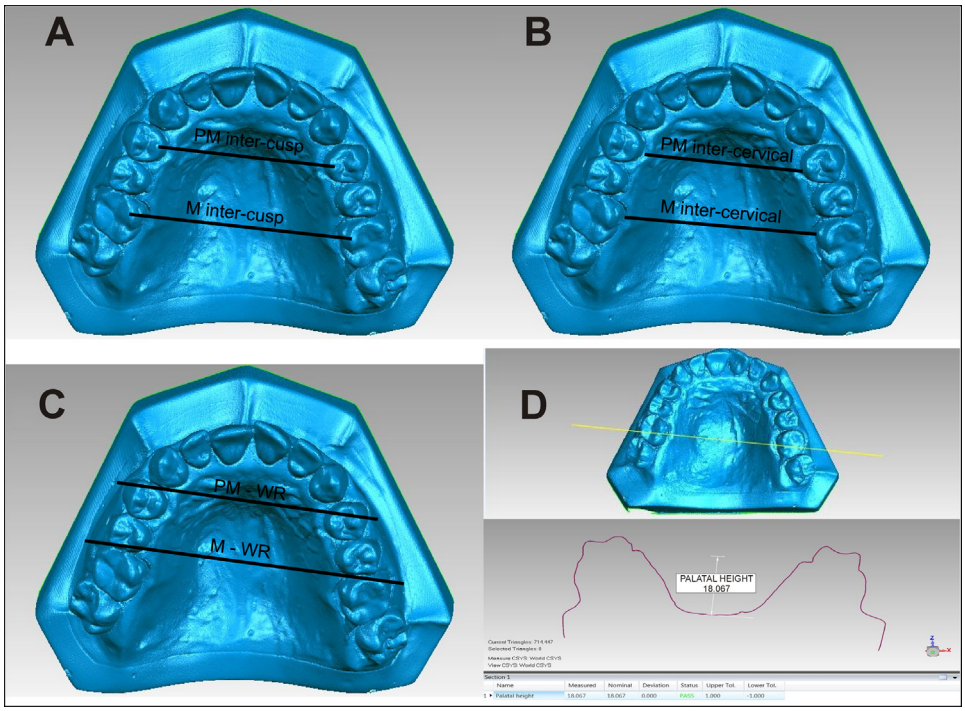

Fig 2. Transverse measurements: **A,** occlusal view of the premolar and molar intercusp distances; **B,** occlusal view of the premolar and molar intercervical distances; **C,** occlusal view of the premolar (P-WR) and molar (M-WR) inter-WALA ridge distances; **D,** *upper*, cross section of a 3D model at the main sulcus area of the palatal side (maxillary first molars), and *lower*, cross-sectional measurement of palatal height.

specific for 3-dimensional (3D) data (Qualify, version 12.0; Geomagic, Rock Hill, SC).

Measurements were made on the digitized images of each plaster cast. The dentoskeletal transverse measurements were the following.

1. Premolar and molar intercusp distances: the distances between the palatal cusp tips of the maxillary first premolars and between the mesiolingual cusp tips of the maxillary first molars (Fig 2, *A*).
2. Premolar and molar intercervical distances: the distance between the most palatal points of the gingival margin of the maxillary first premolars or molars (Fig 2, *A*).
3. Premolar and molar inter-WALA ridge distances: the distances between the most prominent points on the alveolar process of the maxillary first premolars and molars (Fig 2, *B*)
4. Palate height at the maxillary first molar: measured at the cross-section on the 3D model at the main sulcus area of the palatal side of the maxillary first molars to the deepest palatal area (Fig 2, *C* and *D*).

The measurements were made by 2 investigators (G.P.R.P., J.P.R.B.). One investigator made 2 assessments with a 15-day interval between them, and the other investigator made 1 assessment.

Statistical analysis

The Kolmogorov-Smirnov test was used to investigate the normality of the sample distribution.[14]

The participants' ages and the expansion amounts were described per group and compared using the Student *t* test.[13] The associations between the groups and the patients' sex were analyzed using the chi-square test.[14]

To assess the intraexaminer and interexaminer agreements relative to the 3D scanner method, the intraclass correlation coefficient was calculated with the corresponding 95% confidence interval.[15]

All investigated measurements were described by group (with and without retention) and assessment time (preoperative, 4 months, and 10 months) using summary measures and 2-way repeated-measures analysis of variance (ANOVA) relative to the factor of time point.[16] A first-order autoregressive matrix of correlation among the assessment times was assumed.[15] The Tukey multiple comparison test was performed on the measurements with statistical

Table I. Means and corresponding standard deviations before surgery and at 4 and 10 months of the groups with and without retention; results of ANOVA comparing the groups and time points (interaction effects)

		Group		*ANOVA**		
	Period	*NRG (n = 15), Mean (SD)*	*RG (n = 15), Mean (SD)*	*Interaction*	*Time*	*Group*
PM intercusp (mm)	Preop	25.68 (3.58)	27.12 (3.15)			
	4 mo	34.10 (3.55)	35.65 (2.97)	0.004*	<0.001*	0.061
	10 mo	32.26 (3.05)	35.68 (3.20)			
M intercusp (mm)	Preop	34.88 (4.47)	36.03 (3.82)			
	4 mo	43.22 (4.72)	44.91 (3.94)	0.164	<0.001*	0.199
	10 mo	41.73 (4.32)	44.34 (3.44)			
PM intercervical (mm)	Preop	22.78 (3.16)	24.18 (2.58)			
	4 mo	30.89 (2.96)	32.88 (2.57)	0.079	<0.001*	0.035*
	10 mo	29.48 (2.58)	32.38 (2.96)			
M intercervical (mm)	Preop	29.34 (3.93)	30.97 (3.23)			
	4 mo	37.58 (4.16)	39.82 (3.06)	0.095	<0.001*	0.064
	10 mo	36.45 (3.98)	39.48 (2.71)			
PM-WR (mm)	Preop	42.46 (2.57)	43.62 (2.49)			
	4 mo	49.58 (2.74)	51.35 (2.65)	0.276	<0.001*	0.070
	10 mo	48.57 (2.34)	50.59 (2.94)			
M-WR (mm)	Preop	54.46 (4.08)	54.84 (2.70)			
	4 mo	62.11 (3.98)	63.14 (2.89)	0.300	<0.001*	0.454
	10 mo	61.13 (3.99)	62.45 (2.97)			
Palatal height (mm)	Preop	18.22 (2.37)	17.89 (1.62)			
	4 mo	17.22 (2.21)	17.30 (1.94)	0.340	<0.001*	0.987
	10 mo	16.94 (2.24)	17.23 (1.84)			

NRG, No-retention group; *RG*, retention group; *PM*, premolar; *M*, molar; *WR*, WALA ridge; *Preop*, preoperative.
*$P < 0.05$.

significance to determine the relevant groups or time points.[17]

The level of null hypothesis rejection was <5%.

RESULTS

The no-retention and retention patients had average expansions of 8.40 mm (SD, 1.46) and 8.95 mm (SD, 1.22), respectively. The groups did not differ regarding age ($P = 0.609$), sex ($P = 0.456$), or expansion after SAPRE ($P = 0.272$).

The intraexaminer agreement was high relative to both measurements, with an intraclass correlation coefficient exceeding 0.90.

Only the premolar intercusp measurement showed an interaction effect between the groups and over the time points ($P = 0.04$). The premolar intercervical, premolar WALA ridge, molar intercusp, molar intercervical, molar WALA ridge, and molar palatal height measurements had no interaction effects between the groups and the time points ($P > 0.05$) and were statistically similar in both groups over time. All means exhibited significant differences over time ($P < 0.01$). There were no significant differences between groups related to relapse except for the premolar intercusp measurement in the no-retention group (Table I).

All measurements significantly increased at the 4-month time point compared with the preoperative assessment ($P < 0.05$), except for palatal height, which was significantly reduced ($P < 0.01$) (Table II).

A significant relapse of the premolar intercusp distance (1.84 mm, 5.4%) occurred in the no-retention group between 4 and 10 months; this was not observed in the retention group (0.03 mm). Significant relapses of premolar intercervical (0.95 mm, 2.99%), premolar WALA ridge (0.88 mm, 1.75%), molar intercusp (1.04 mm, 2.35%), molar intercervical (0.74 mm, 1.90%), and molar WALA ridge (0.84 mm, 1.34%) distances were found in both groups at the 10-month time point. A nonsignificant reduction of palatal height (0.18 mm, 1.02%; $P = 0.520$) was found at the 10-month time point (Table II).

DISCUSSION

Stability can be assessed based on relapse extent (in millimeters) after removal of the expanders.[3,18] Relapse must then be assessed by comparing the absolute average differences between the measurements at 4 and 10 months. According to Aloise et al,[3] relapse analysis must

Table II. Results of multiple comparisons (Tukey test) per group and time point

Variable	*Comparison*		*Estimated average difference*	*SE*	P
PM intercusp (mm)	Without retention (preop)	Without retention (4 mo)	−8.42	0.38	<0.001
	Without retention (preop)	Without retention (10 mo)	−6.58	0.52	<0.001
	Without retention (4 mo)	Without retention (10 mo)	1.84	0.38	<0.001
	With retention (preop)	With retention (4 mo)	−8.52	0.38	<0.001
	With retention (preop)	With retention (10 mo)	−8.56	0.52	<0.001
	With retention (4 mo)	With retention (10 mo)	−0.03	0.38	>0.999
	Without retention (preop)	With retention (preop)	−1.44	1.15	0.807
	Without retention (4 mo)	With retention (4 mo)	−1.54	1.15	0.759
	Without retention (10 mo)	With retention (10 mo)	−3.42	1.15	0.047
M intercusp (mm)	Preop	4 mo	−8.61	0.29	<0.001
	Preop	10 mo	−7.58	0.40	<0.001
	4 mo	10 mo	1.04	0.29	0.002
PM intercervical (mm)	Without retention	With retention	−2.14	0.94	0.031
	Preop	4 mo	−8.40	0.25	<0.001
	Preop	10 mo	−7.45	0.34	<0.001
	4 mo	10 mo	0.95	0.25	0.001
M intercervical (mm)	Preop	4 mo	−8.54	0.24	<0.001
	Preop	10 mo	−7.80	0.33	<0.001
	4 mo	10 mo	0.74	0.24	0.008
PM-WR (mm)	Preop	4 mo	−7.42	0.21	<0.001
	Preop	10 mo	−6.54	0.29	<0.001
	4 mo	10 mo	0.88	0.21	<0.001
M-WR (mm)	Preop	4 mo	−7.98	0.23	<0.001
	Preop	10 mo	−7.14	0.32	<0.001
	4 mo	10 mo	0.84	0.23	0.002
Palatal height (mm)	Preop	4 mo	0.79	0.16	<0.001
	Preop	10 mo	0.97	0.22	<0.001
	4 mo	10 mo	0.18	0.16	0.520

PM, Premolar; *M*, molar; *WR*, WALA ridge; *preop*, preoperative.

account for the influence of SARPE, which differs in the anterior (first premolar) and posterior (first molar) areas.

The premolar intercusp distance increased between the preoperative evaluation and the 2 subsequent assessments, confirming the results of Sokucu et al.[19] However, a significant relapse (1.84 mm, 5.4%) was observed at the 10-month time point in the no-retention group only; this was most likely due to the lack of transpalatal arch anterior prolongation.

The molar intercusp distance relapse observed between 4 and 10 months was 1.04 mm (2.35%). Northway and Meade[20] observed relapses in their SARPE group; however, the comparison with the preoperative groups occurred after fixed orthodontic treatment, which might have influenced the relapse and, thus, the results. Those authors found a 5% to 6% relapse in the molars, possibly associated with the nonrelease of the pterygomaxillary fissure. Berger et al[21] found a 17.5% relapse in the molars 1 year after SARPE; however, they did not separate the pterygoid processes. Anttila et al[22] assessed stability after SARPE with and without disjunction of the pterygoid processes after orthodontic treatment, as well as long-term relapse (at least 2 years after orthodontic treatment), and found a 0.5-mm (29%) difference in the molars.

The premolar intercervical distance was on average 2.14 mm greater in the retention group compared with the no-retention group at all time points. However, that difference was observed at the preoperative assessment. The measurement had an average significant increase of 8.40 mm (35.78%) in both groups between the preoperative and 4-month assessments. At 10 months, a significant average relapse of 1 mm (2.99%) was observed. In most cases, transverse maxillary deficiencies (of variable magnitude) are more remarkable in the molar area than in the premolar area. Therefore, the parallel opening of the median palatal suture along the anteroposterior direction (arising from the pterygoid process release) overcorrects that region. Thus, a slight relapse in the premolar region is desirable, and this actually occurred in the no-retention group. Nevertheless, ideally, the expansion required by each area should be individualized, and separate expanders should be used, as suggested by Timms[23] and Strömberg and Holm.[24]

A relapse of 0.74 mm (1.9%) was found relative to the molar intercervical distance between 4 and 10 months. This relapse was the smallest in absolute terms, but its

percentage was quite similar to that of Aloise et al.[3] The study by Strömberg and Holm[24] yielded similar results. Divergence relative to our study concerned the assessment time points because the abovementioned authors conducted long-term evaluations but not pterygoid-process release.

The premolar and molar WALA ridge distances significantly increased between the preoperative and subsequent time points. Between 4 and 10 months, the relapse amounts were 0.88 (1.75%) in the premolars and 0.84 mm (1.34%) in the molars. Although those differences were statistically significant, they are not clinically relevant because these values were not close to the initial values. Since skeletal transverse measurements were used, their analysis has paramount importance because the main goal of SARPE is to correct transverse skeletal deficiencies. It was not possible to compare the results with the literature because of the lack of SARPE studies with the WALA ridge as a reference.

In contrast with the remaining dental and skeletal measures, the palatal height at the first molar area was significantly reduced on average between the preoperative and subsequent time points in both groups. This measurement represents the effect of SARPE on the palate depth reduction in the molar area; this is due to the downward motion of the maxilla after disjunction. Relapse was not found at 10 months. Conversely, palatal height at the molar area exhibited a reduction of 0.18 mm that was not statistically significant; thus, the overall effect remained stable. No studies assessing the effect of SARPE on reducing palatal height with the 3D methods used here were found in the literature.

Both groups exhibited a small relapse in the bone measurements (cervical area and WALA ridge), indicating that a transpalatal arch is unnecessary. Furthermore, a possible strategy to prevent tooth relapse (measurement on cusps) might be either to start orthodontic treatment immediately after removing the hyrax device or to leave the hyrax for longer than 6 months. A long-term follow-up (more than 2 years) without any orthodontic appliance is needed to evaluate dento-osseous relapse.

CONCLUSIONS

The analysis of relapse in both groups suggests that the use of a transpalatal arch as a retaining device does not improve dento-osseous stability.

REFERENCES

1. Betts NJ, Vanarsdall RL, Barber HD, Higgins-Barber K, Fonseca RJ. Diagnosis and treatment of transverse maxillary deficiency. Int J Adult Orthod Orthognath Surg 1995;10:75-96.
2. Bays RA, Greco JM. Surgically assisted rapid palatal expansion: an outpatient technique with long-term stability. J Oral Maxillofac Surg 1992;50:110-3.
3. Aloise AC, Pereira MD, Hino CT, Filho AG, Ferreira LM. Stability of the transverse dimension of the maxilla after surgically assisted rapid expansion. J Craniofac Surg 2007;18:860-5.
4. Lagravère MO, Major PW, Flores-Mir C. Dental and skeletal changes following surgically assisted rapid maxillary expansion. Int J Oral Maxillofac Surg 2006;35:481-7.
5. Suri L, Taneja P. Surgically assisted rapid palatal expansion: a literature review. Am J Orthod Dentofacial Orthop 2008;133:290-302.
6. Tiago CM, Gurgel JA. The amount of dental and skeletal expansion and stability after surgically assisted rapid maxillary expansion: a systematic review. Ortod SPO 2011;44:13-21.
7. Kusnoto B, Evans CA. Reliability of a 3D surface laser scanner for orthodontic applications. Am J Orthod Dentofacial Orthop 2002; 122:342-8.
8. Oliveira NL, Da Silveira AC, Kusnoto B, Viana G. Three-dimensional assessment of morphologic changes of the maxilla: a comparison of 2 kinds of palatal expanders. Am J Orthod Dentofacial Orthop 2004;126:354-62.
9. Rheude B, Sadowsky PL, Ferriera A, Jacobson A. An evaluation of the use of digital study models in orthodontic diagnosis and treatment planning. Angle Orthod 2005;75:300-4.
10. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs digital study models: comparison of peer assessment rating and Bolton analysis and their constituent measurements. Am J Orthod Dentofacial Orthop 2006;129:794-803.
11. Keating AP, Knox J, Bibb R, Zhurov AI. A comparison of plaster, digital and reconstructed study model accuracy. J Orthod 2008; 35:191-201.
12. Oliveira De Felippe NL, Da Silveira AC, Viana G, Kusnoto B, Smith B, Evans CA. Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: short- and long-term effects. Am J Orthod Dentofacial Orthop 2008;134: 370-82.
13. Hayashi K, Sachdeva AU, Saitoh S, Lee SP, Kubota T, Mizoguchi I. Assessment of the accuracy and reliability of new 3-dimensional scanning devices. Am J Orthod Dentofacial Orthop 2013;144: 619-25.
14. Kirkwood BR, Sterne JA. Essential medical statistics. 2nd ed. Malden, Mass: Blackwell Science; 2006.
15. Fleiss JL. The design and analysis of clinical experiments. New York: Wiley; 1986.
16. Singer JM, Andrade DF. Analysis of longitudinal data. In: Sen PK, Rao CR, editors. Handbook of statistics, volume 18. Amsterdam, The Netherlands: Elsevier; 2000. p. 115-60.
17. Neter J, Kutner MH, Nachtsheim CJ, Wasserman W. Applied linear statistical models. 4th ed. Burr Ridge, Ill: Irwin; 1996.
18. Koudstaal MJ, Wolvius EB, Schulten AJ, Hop WC, van der Wal KG. Stability, tipping and relapse of bone-borne versus tooth-borne surgically assisted rapid maxillary expansion; a prospective randomized patient trial. Int J Oral Maxillofac Surg 2009;38:308-15.
19. Sokucu O, Kosger HH, Bicakci AA, Babacan H. Stability in dental changes in RME and SARME: a 2-year follow-up. Angle Orthod 2009;79:207-13.
20. Northway WM, Meade JB Jr. Surgically assisted rapid maxillary expansion: a comparison of technique, response, and stability. Angle Orthod 1997;67:309-20.
21. Berger JL, Pangrazio-Kulbersh V, Borgula T, Kaczynski R. Stability of orthopedic and surgically assisted rapid palatal

expansion over time. Am J Orthod Dentofacial Orthop 1998;114: 638-45.
22. Anttila A, Finne K, Keski-Nisula K, Somppi M, Panula K, Peltomaki T. Feasibility and long-term stability of surgically assisted rapid maxillary expansion with lateral osteotomy. Eur J Orthod 2004;26:391-5.
23. Timms DJ. An occlusal analysis of lateral maxillary expansion with midpalatal suture opening. Dent Pract Dent Rec 1968;18: 435-41.
24. Stromberg C, Holm J. Surgically assisted, rapid maxillary expansion in adults. A retrospective long-term follow-up study. J Craniomaxillofac Surg 1995;23:222-7.