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Lateral cephalometry changes after SARPE

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Abstract. Surgically assisted rapid palatal expansion (SARPE) is associated with postoperative cephalometric changes. In this study we analyse these changes in the sagittal plane in orthognathic patients undergoing SARPE followed by orthodontic treatment and Le Fort I, bilateral sagittal split osteotomy (BSSO), or bimaxillary surgery. This is a retrospective review of 50 patients (20 males, 30 females) undergoing orthognathic treatment with SARPE to correct transversal deficiency of the maxilla as part of a comprehensive treatment plan. PP-SN, SNA, and ANB angles were increased and U1-SN and U1-PP angles were decreased. All changes were statistically significant. Changes of SNB, PP-Mand plane angle, and SN-Mand. plane angle were not statistically significant. Surgically assisted rapid palatal expansion using a bone-borne appliance as a preparative step for later orthognathic surgery results in clockwise rotation of the maxilla.

Key words: surgically assisted rapid palatal expansion; SARPE; lateral cephalometry changes.

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In orthognathic surgery, correction of the maxillary transversal dimension via Le Fort I expansion osteotomy is one of the least stable movements[21,22]. Relapse is most common during the first postoperative year. The authors' approach to correct transverse maxillary deficiency in non-syndromic adolescent or adult orthognathic patients is to perform multisegmental Le Fort I osteotomy when an expansion of less than 5 mm in the molar area is needed in adults or when a dual-plane maxilla is present. In other cases, a preliminary surgically assisted rapid palatal expansion (SARPE) is preferred[19]. This operation is performed at least 1 year before the planned Le Fort I procedure and allows for simultaneous extraction of premolars and/or third molars, because of the bone-borne nature of the transpalatal distractor.

Transverse maxillary hypoplasia is a frequent finding in non-syndromic adolescents and adults[20]. Non-surgical treatment options to correct transverse maxillary hypoplasia in children and young adolescents are slow maxillary expansion (SME) for mild discrepancies or rapid maxillary expansion (RME) for more severe cases. Owing to the increased skeletal resistance, RME in adults is associated with alveolar bending, periodontal ligament compression, buccal root resorption of the anchor teeth, fenestration of the buccal cortical plate, and tipping and extrusion of the anchor teeth[2]. The negative effects are presumably due to the tooth-borne anchorage of conventional appliances. Tooth-borne appliances deliver stress to the roots and periodontal ligament as well as the alveolar bone during expansion. Additionally, the bony movement is not retained during the consolidation period[27]. This led to the introduction of the first bone-borne appliance (distractor) in 1999, which delivers the expansion force directly to the maxillary bone and avoids the negative orthodontic and periodontal effects[15].

After Mommaerts introduced the 'Transpalatal Distractor' (TPD) in 1999, researchers evaluated the dental and skeletal effects of this appliance. Most of these studies focused on the amount of transverse expansion after activating TPD or its dental and periodontal effects[8,14,18,23,26]. In this study the authors analyse the lateral cephalometric changes associated with TPD.

Materials and methods

Of 280 patients treated by SARPE using TPD from July 2000 to February 2010 in Hasselt University, Belgium, 50 patients

(20 male, 30 female) who also underwent orthognathic surgery after palatal expansion were selected.

Pretreatment records, including posteroanterior (PA) and lateral cephalograms, panoramic and periapical radiographs, intraoral and extraoral photographs, and study models were taken for all patients. The lateral cephalometric radiograph was taken using the Orthophos XG Plus (SIRONA Company). Using Onyx software, the SNA, SNB, ANB, PP-SN plane angle, PP-Mand. (angle between palatal plane and mandibular plane), SN-Mand. angle (angle between SN plane and mandibular plane), U1-palatal plane angle, and U1-SN plane angle were measured and recorded (Fig. 1).

Under general anaesthesia, MOMMAERTS' TPD appliance[15] was mounted onto the molar region of the palate. Mid-palatal osteotomy with Le Fort I osteotomy and nasal and pterygopalatal disjunction was performed in all patients (Fig. 2). Adequate mobilization of the maxillary halves was checked both with the osteotome and with activation of the TPD, until a central diastema of a few millimetres was reached. The TPD screw was then turned until a central diastema of 1 mm was reached and the lock screw was placed. In patients requiring only minimal expansion in the anterior region and wide expansion in the posterior region, an anterior blockage was applied from the left to the right upper incisor. Between the fifth and seventh postoperative days, patients were evaluated for removal of the lock screw and to begin activation of the TPD at 120° (0.33 mm) a day. During the activation period, patients were seen each week until the desired expansion was achieved. No overcorrection was done. 12 weeks after surgery, the patient's orthodontist started orthodontic treatment. The distractor was kept in place for a maximum of 9 months to minimize the risk of relapse. After completion of orthodontic treatment, standard imaging (panoramic radiograph, PA, lateral cephalograms and occlusal view) were taken. Postoperatively, the SNA, SNB, ANB, PP-SN plane, PP-Mand. angle, SN-Mand. angle, U1-palatal plane, and U1-SN plane angle changes were evaluated.

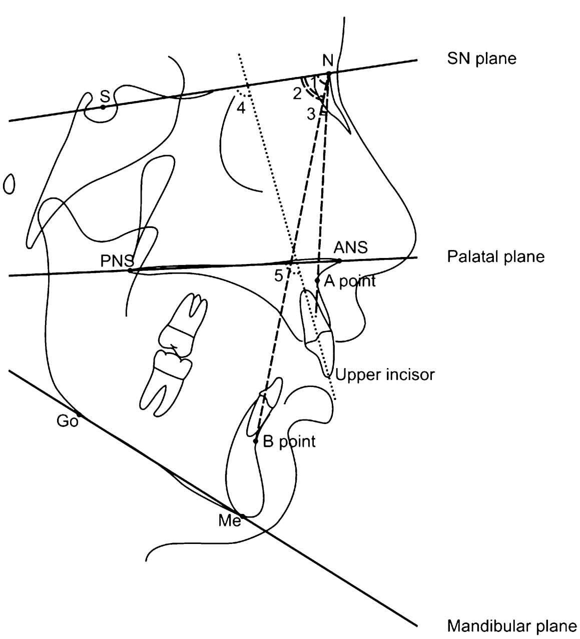

Fig. 1. Cephalometric tracing illustrating measurements of SNA (angle 1), SNB (angle 2), ANB (angle 3), U1-SN (angle 4), U1-PP (angle 5), PP-SN plane angle (angle between palatal plane and SN plane), PP-mandibular plane angle (angle between palatal plane and mandibular plane), and SN-mandibular plane angle (angle between SN plane and mandibular plane). Greatest depression point in the anterior of maxilla (A point), greatest depression point in the anterior mandibular (B point), middle of sella (S point), junction of the nose and the frontal bone (N), plane passed from coronal tip and root apex of the central incisors (U1), plane from anterior nasal spine to posterior nasal spine (palatal plane or PP plane), plane passed from S point and N point (SN plane), plane from menton point to gonial angle of the mandible (mandibular plane), angle made by S point and N point and A point (SNA angle), angle made by S point and N point and B point (SNB angle), angle made by A point and N point and B point (ANB angle), angle between SN plane and palatal plane (PP-SN plane angle), angle between SN plane and mandibular plane (SN-Mand. plane angle), angle between palatal plane and mandibular plane (PP-Mand. plane angle), angle between U1 and the SN plane (U1-SN plane angle), angle between U1 and palatal plane (U1-PP plane angle).

Statistical methods

To evaluate patterns within the data, EDA was performed. Descriptive statistics including means and standard deviations (SD) for each measurement of each angle were calculated.

Student's paired *t*-test was used to compare preoperative and postoperative data for each patient. The paired *t*-test provides a hypothetical evaluation of the difference between population means for a pair of random samples whose differences are approximately normally distributed.

Regression analysis was performed to investigate the ability to predict postoperative PP-SN angle based on patient characteristics.

The Institute for Biostatistics at Hasselt University performed all statistical analyses.

Results

The patient group consisted of 50 patients, 35 (70%) had class II occlusion and 15 (30%) had class III occlusion. The average age of the participants was 26 years (range 15–49 years); none were younger than 15 years. Follow-up measurements were performed after completion of orthodontic alignment of the upper and lower jaw before orthognathic surgery (Le Fort I, bilateral sagittal split osteotomy (BSSO), bimaxillary surgery) (20 ± 9 months).

EDA

Table 1 shows that angles did not change in a minority of patients. Most patients had decreased UI-SN and UI-PP angles and increased SNA, PP-SN, and ANB angles after surgery. For PP-Mand., SN-Mand., and SNB, the number of patients with increasing versus decreasing angles were similar. This is confirmed by paired *t*-test analysis (Table 2).

For U1-SN and U1-PP angles, the majority of patients had a decreased measurement following surgery. For the PP-SN, SNA, and ANB angles more patients had increased rather than decreased values. Student's paired *t*-test was used to determine the statistical significance of these changes.

Student's paired *t*-test

Changes in U1-SN and U1-PP angles (retroclination of upper incisors towards SN or PP, respectively) and PP-SN, SNA,

Fig. 2. The treatment sequence in all patients in this study was SARPE TPD as a first step, followed by orthodontic alignment and subsequent maxillary and/or mandibular orthognatic surgery.

and ANB angles (clockwise rotation of palatal plane and increase of SNA and ANB) were statistically significant (Fig. 3). Changes in PP-Mand., SNB, and SN-Mand. were not statistically different.

PP-SN plane angle

As shown in Fig. 3, the PP-SN plane angle increased after surgery. On regression analysis, only a few response variables were available for analysis (PP-SN post jaw surgery with the covariates PP-SN pre surgery, gender, age, and occlusion). Table 3 shows that after TPD, male patients had a higher tendency towards a clockwise rotation of PP than female patients. This is indicated in the boxplot diagram in Fig. 4. Table 4 shows descriptive statistics for PP-SN by occlusion. Class II patients tend to have smaller PP-SN values than Class III patients both pre- and post-SARPE (Fig. 5).

To determine if age affects PP-SN angle after surgery, the authors created a scatter plot (Fig. 6). As Fig. 6 shows, there is no relationship between age and PP-SN plane angle.

The correlation between PP-SN angle before (PP-SN pre) and after (PP-SN post) SARPE was established and is shown with the scatter plot presented in Fig. 7. Patients with a lower PP-SN before surgery tend to have a lower PP-SN postoperatively. A higher preoperative PP-SN was associated with a higher postoperative PP-SN (post). The correla-

Table 1. The number of patients with or without changes in lateral cephalometric angles before and after surgery.

Angle (°)	Direction of change		
	Increase (+)	Decrease (−)	No change (difference = 0)
UI-SN	13	35	2
UI-PP	13	36	1
PP-SN	29	11	10
PP-Mand.	23	22	5
SNA	35	9	6
SNB	22	21	7
ANB	30	7	13
SN-Mand.	29	16	5

Angle between U1 and the SN plane (U1-SN plane angle).
Angle between U1 and palatal plane (U1-PP plane angle).
Angle between SN plane and palatal plane (PP-SN plane angle).
Angle between palatal plane and mandibular plane (PP-Mand. plane angle).
Angle made by S point and N point and A point (SNA angle).
Angle made by S point and N point and B point (SNB angle).
Angle made by A point and N point and B point (ANB angle).
Angle between SN plane and mandibular plane (SN-Mand. plane angle).

Table 2. Student's paired *t*-test results.

Angle (°)	Pre surgery		Post surgery		Change		95% CI Change		Prob.
	Mean	SD	Mean	SD	Mean	SD	Lower	Upper	
U1-SN	102.6	9.39	97.78	8.32	−4.82	8.94	−7.36	−2.28	0.000*
U1-PP	108.22	9.33	104.36	8.33	−3.86	8.56	−6.29	−1.43	0.002
PP-SN	5.62	3.66	6.56	3.89	0.94	2.13	0.33	1.55	0.003*
PP-Mand.	34.88	7.78	34.66	8.47	−0.22	3.38	−1.18	0.74	0.648
SNA	80.3	4.08	81.9	3.74	1.60	2.57	0.87	2.33	0.000*
SNB	76.46	5.54	76.92	5.80	0.46	2.61	−0.28	1.20	0.219
ANB	3.94	4.38	5	4.30	1.06	2.00	0.49	1.63	0.000*
SN-Mand.	40.5	7.67	41.16	8.19	0.66	3.03	−0.20	1.52	0.131

* Changes statistically significant with $\alpha = 5\%$.The null hypothesis is that there is no change after SRPE in the sagittal planes or angles (two sided Student's paired *t*-test).For abbreviations see Table 1.

tion between PP-SN before and after surgery is 0.84.

Regression analysis

Both the available covariates and their possible interactions were included to find the best statistical model. Confirmation of the assumption of regression analysis is also needed. The following model was reached:

$$\hat{y} = -1.331 + 0.897\ \text{PPSNpre} + 1.483\ \text{GENDER} + 0.063\ \text{AGE} + 0.768\ \text{OCCLUSION}$$

The significance of each covariate can be seen in Table 5. The presurgical PP-SN angle has a significant effect on postoperative PP-SN angle. A unit increase in PP-SN before surgery leads to an increase in the post surgery PP-SN angle of 0.897 when other variables are held constant. Gender also affects PP-SN angle. Male patients tend to have an increased angle post surgery compared with female patients. The covariates, age and occlusion, had no significant effect on post-operative PP-SN. In the regression analysis, no assumption is violated.

Coefficient determination for this model is 0.753, meaning that 75.3% of the total variance in Y (PP-SN plane angle after surgery) can be explained by PP-SN (preoperative value), gender, age, and occlusion. The remaining 24.7% of the total variation value in angle PP-SN post surgery remains unexplained.

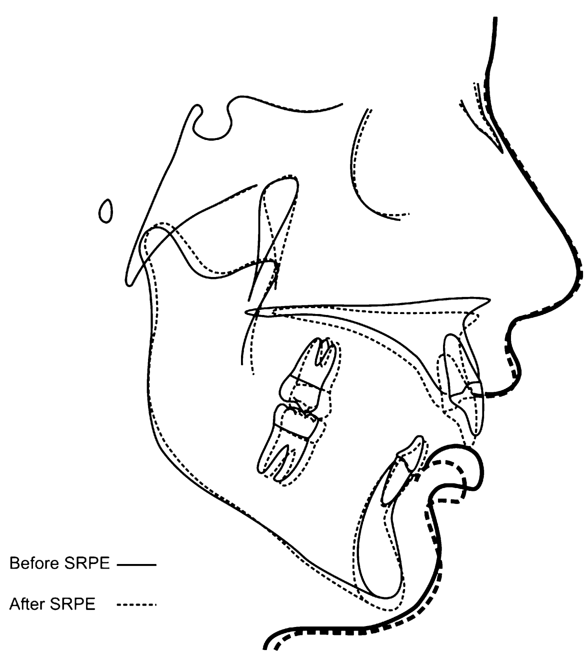

Fig. 3. Superimposition of lateral cephalometry before and after surgery shows that the PP-SN plane angle is increased. This increase is statistically significant ($P = 0.003$*).

Table 3. Descriptive statistics of PP-SN angle by gender.

Gender		*N*	Minimum	Maximum	Mean	SD
Female	PP-SN(pre)	30	−1	15	5.20	3.458
	PP-SN(post)	30	0	16	5.77	3.839
Male	PP-SN(pre)	20	1	15	6.25	3.945
	PP-SN(post)	20	1	16	7.75	3.740

Angle between SN plane and palatal plane (PP-SN plane angle).

U1-PP and U1-SN plane angles

All patients in this study had orthodontic alignment (pre-Le Fort I, pre-BSSO, pre-bimaxillary surgery) before second standard radiographs were taken. The U1-PP and U1-SN plane angles decreased after SARPE. Tables 6 and 7 show the minimum, maximum, mean, and standard deviation value of U1-SN and U1-PP angles by gender.

The U1-PP angle and U1-SN angle is decreased after SARPE TPD in both male and female patients. In females the changes before and after surgery in both U1-SN plane angle and U1-PP plane angle is statistically greater than in males (Student's paired *t*-test).

The patients were grouped based on U1-SN angle before SARPE. Patients with normal U1-SN angle (within the range 104–106°) are included in the first group (9 patients). Patients who have U1-SN less than 103° and greater than 106° are included in group 2 (lower than normal: 25 patients) and 3 (greater than normal: 16 patients), respectively.

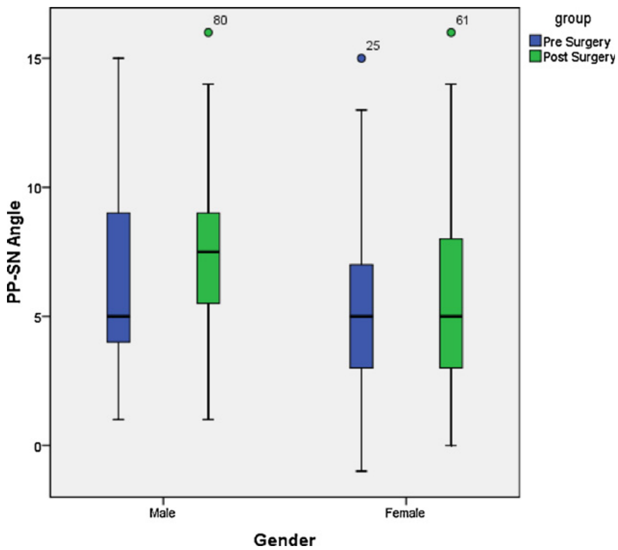

Fig. 4. Boxplot for PP-SN angle pre-SARPE and post-SRPE by gender.

Table 4. Descriptive statistic of PP-SN angle by occlusion.

Occlusion		*N*	Minimum	Maximum	Mean	SD
Class III	PP-SN(pre)	15	1	15	6.67	4.100
	PP-SN(post)	15	1	16	7.13	3.662
Class II	PP-SN(pre)	35	−1	13	5.17	3.417
	PP-SN(post)	35	0	16	6.31	4.006

Angle between SN plane and palatal plane (PP-SN plane angle).

The boxplots of changes of U1-SN angle before and after SARPE for the three U1-SN groups are presented in Fig. 8. For patients with a normal presurgical angle, a normal value after SARPE and subsequent orthodontic alignment is expected. The results show that this is not the case. Most patients show a decrease in U1-SN following surgery. Patients with a lower than normal UI-SN prior to surgery, on average, tend to have a stable angle (no further decrease). Only a few patients in this group showed an increasing U1-SN. In patients with a presurgical U1-SN above average, there was a trend towards a decrease of this angle after SARPE.

Similarly, the patients were grouped based on the preoperative U1-PP angle.

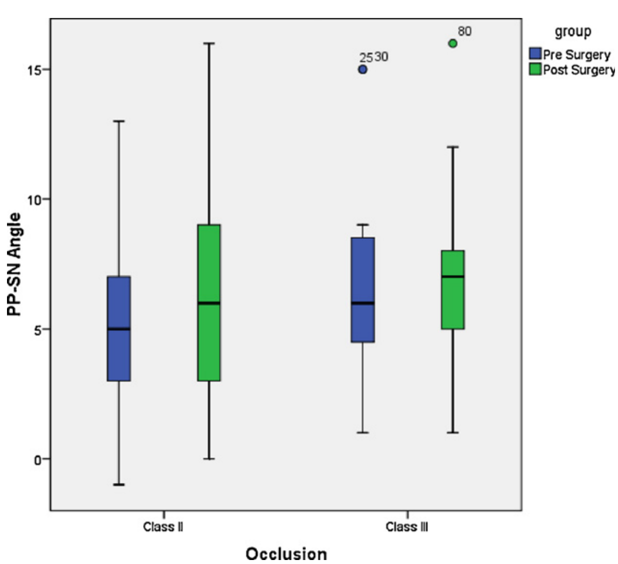

Fig. 5. Boxplot for PP-SN angle pre-surgery and post-surgery by occlusion.

Patients with a normal U1-PP angle (within the range 110–116°) are included in the first group (11 patients). Patients with a U1-PP less than 110° and greater than 117° were assigned to groups 2 (lower than normal: 27 patients) and 3 (greater than normal: 12 patients), respectively. The box plot of angle changes for U1-PP groups is presented in Fig. 9.

Changes similar to that seen with U1-SN also occur for the U1-PP angle. After surgery, the patients with normal U1-PP angles tend to have a decreased angle, whereas on average, patients with lower preoperative angles tended to have a stable U1-PP angle. The variability in this group is quite high, with some having normal postoperative U1-PP values and some with abnormal values. Patients whose preoperative U1-PP angle was higher than normal had a decreased angle after SARPE.

One of the limitations of this study is that only a few covariables were available for regression analysis (age, gender, occlusion, pre-SARPE values). Other important variables that could affect outcome were not available owing to the retrospective nature of this study: the type of orthodontic appliances, the exact amount of transverse expansion, the sagittal position of the TPD device, and the vertical position of the brackets on the incisors. A systemic review of the effects of bone-borne surgical assisted rapid maxillary expansion[27] indicates no additional covariant factor in this respect.

Discussion

The preliminary surgical correction of transverse maxillary discrepancies in patients with planned subsequent orthognathic treatment is different from that in which the SARPE procedure is the sole intervention. In the first scenario, the inclination of the upper front teeth is intended to be corrected on the maxillary base by the orthodontic presurgical alignment, independent of the relation with the lower jaw. The authors have previously provided the rationale for this approach, based on timing, amount of maxillary expansion, and stability issues. Whenever subsequent surgery is planned, the inclination of U1-PP is aimed at approximately 112° (range 110–114°), except in treatment plans where a posterior intrusion of the upper jaw calls for a presurgical inclination of U1-PP greater than 112°. The transversal gain by the preliminary SARPE should not be compromised by undesired sagittal or vertical changes.

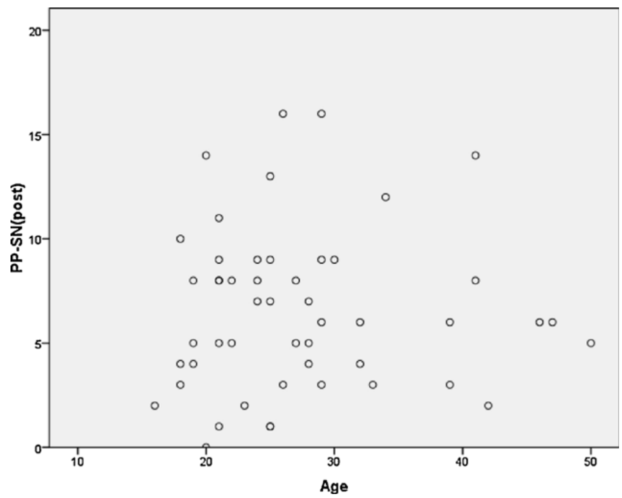

Fig. 6. Scatter plot of age and PP-SN post surgery.

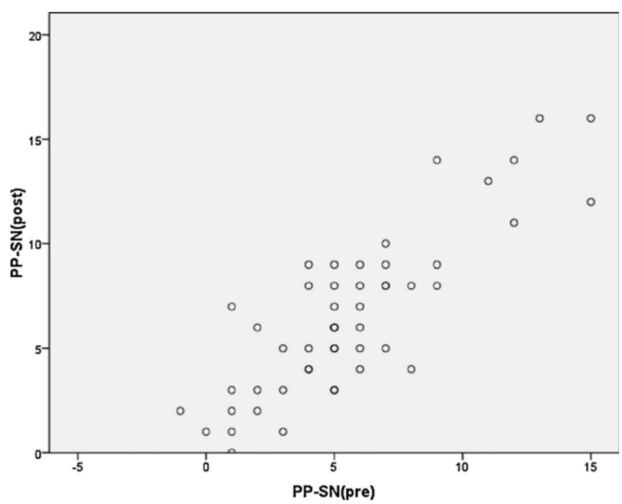

Fig. 7. Scatter plot of PP-SN before and after surgery.

Table 5. Coefficient of regression and their significance for model angle PP-SN post surgery.

Model	Coefficients		t	Sig.
	B	SE		
(Constant)	−1.331	1.296	−1.027	.310
PPSN(pre)	.897	.081	11.133	.000*
Gender	1.483	.619	2.396	.021*
Age	.063	.036	1.740	.089
Occlusion	.768	.656	1.170	.248

Angle between SN plane and palatal plane (PP-SN plane angle).
*The covariate is statistically significant with $\alpha = 5\%$.

Table 6. Descriptive statistic of U1-SN angle by gender.

	Gender	N	Minimum	Maximum	Mean	SD
Male	U1-SN(pre)	20	84	124	102.35	9.965
	U1-SN(post)	20	86	119	101.60	6.707
Female	U1-SN(pre)	30	80	121	102.77	9.153
	U1-SN(post)	30	76	110	95.23	8.406

Angle between U1 and the SN plane (U1-SN plane angle).

Little is known about the sagittal changes after surgical expansion of the upper jaw with bone-borne appliances. In Table 8, two studies concerning SARPE with bone-borne appliances are summarized. These trials report results similar to the present study: an increase in SNA and ANB (significant in the study by Günbay et al.[10], nonsignificant in the study by Lagravère et al.[12]) and a retroclination of the upper incisors (significant in the present study but nonsignificant in the Lagravère et al. study[12]).

Also in Table 8, four studies concerning SARPE with tooth-borne appliances are presented. Gilon et al.[9] reported a maxillary expansion of 5 mm (range 1.5–8.5 mm) and a nasal expansion of 4.4 mm (2.2–6.6 mm). Vertically, they also found a significant anterior rotation of the palatal plane of 1.58 (−0.6 to −3.6 mm) and sagittally a decrease of the SNB angle of 1.788 (−0.2 to −3.8 mm). This is similar to the present findings.

Lagravere et al.[13] performed a systematic review and concluded that using a tooth-borne device for SARPE results in a greater expansion at the molars, which diminished progressively to the anterior part of the dental arch in all the evaluation periods. Vertical and sagittal skeletal changes were minimal or not clinically significant. In cases of SARME using the HAAS appliance, Chung et al.[5] reported anterior movement as well as vertical movement of the maxillary halves, without significance. Chung et al.[5] also found that the maxillary incisors slightly but significantly retroclined after surgically assisted RPE.

Neubert et al.[17] reported maxillary changes immediately after surgery, but no vertical or sagittal maxillary displacement was found. In the Neubert study the skeletal expansion was small at 1.7 mm.

More literature is found concerning sagittal changes after non-surgical expansion of the upper jaw. In 1961, Haas[11] described the downward and forward movement of the maxilla that occurs during rapid maxillary expansion (tooth-borne device) because of the location of the craniomaxillofacial sutures. This phenomenon has a favourable effect on skeletal class III patients with maxillary deficiency.

Similar results were reported by Davis and Kronman[7] and Wertz[28]. However, Da silva filho et al.[6] found no significant alterations of the maxilla in the anteroposterior position for young patients who underwent orthopaedic RPE, although the mandible had some downward and

Table 7. Descriptive statistic of U1-PP angle by gender.

Gender		*N*	Minimum	Maximum	Mean	SD
Male	U1-PP(pre)	20	90	126	108.60	9.864
	U1-PP(post)	20	95	120	109.25	6.155
Female	U1-PP(pre)	30	85	125	107.97	9.122
	U1-PP(post)	30	87	116	101.10	8.062

Angle between U1 and palatal plane (U1-PP plane angle).

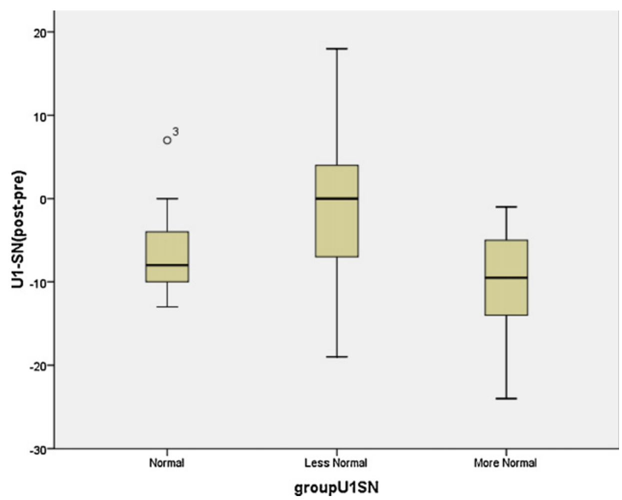

Fig. 8. Box plot of the change of U1-SN angle before and after SARPE.

backward rotation. They also found that the maxilla was dislocated downward, displaying a downward and backward rotation in the palatal plane, which can result in increasing facial height[6]. These results are similar to the present study.

In their investigation of the effects of orthopaedic RPE on maxillary incisors, Wertz[28], Sandikcioglu and Hazar[24], and Akkaya et al.[1] reported incisor retroclination and an increase of the interincisal angle after maxillary expansion. Davis and Kronman[7] indicated that the ‘A’ point moves forward as a result of splitting the palatal suture. They also show that the SN-PP (palatal plane) angle increases in approximately half of the cases with a resultant lowering of the ‘A’ point; the mandibular plane angle tends to increase, thus opening the bite in half of the cases and closing the bite in three cases. These results are similar to the present study.

Wertz[28] showed that the maxilla was routinely displaced downward 1–2 mm, but rarely moves forward significantly. The vertical displacement of the maxilla varied from ANS to PNS, so that the SN-palatal plane angle sometimes opened and sometimes closed. Sometimes the palate descended in a parallel manner, but opening of the SN-PP angle predominated. The ANB angle tended to be increased, but frequently it was decreased.

In a RPE study, Chung and Font[4] show that SNA and ANB increased and SNB decreased, although these decreases were not statistically significant. Both ANS and PNS moved significantly downward. The MP-SN angle increased and suggested a downward and backward rotation of the mandible. The PP-SN did not change significantly, but the PP-MP increased significantly. Previous studies by Davis and Kronman[7], Wertz[28], and Da silva filho et al.[6] also showed an increase in the mandibular plane angle.

Using a bonded RPE appliance (with occlusal coverage), Akkaya et al.[1] reported that the maxilla moved forward and the mandible moved backward. Therefore, the ANB and mandibular plane angle increased significantly after expansion. Similar results were reported by Basciftci and Karaman[3] but Sarver and Johnston[25] reported that the maxilla moved forward less in the bonded RPE sample than in the banded RPE sample. They found the maxilla even moved backward in some bonded RPE patients.

Monini et al.[16] performed a prospective study on children younger than 12 years showing that after RME, an improvement of nasal flow and resistance was recorded in patients in the supine position. They also concluded that PP-Mand. plane angle and SN-Mand. plane angle will decrease (non significantly) and this would be related to the change from oral to nasal breathing, with a consequent mandible autorotation and reduction of facial height.

As the increase in PP-SN, SNA, and ANB was statistically significant in the current study, the data confirm that maxillary expansion is followed by downward rotation of the maxilla. This is independent of the surgical or non-surgical approach but possibly dependent on the amount of transversal expansion.

In the present study, the authors found that the decrease of the U1-SN and U1-PP angles were statistically significant. The decrease in U1-SN plane angle is in part due to clockwise rotation of palatal plane, but the U1-PP plane angle is also decreased. Since the study concerned patients with presurgical alignment, the authors expected that no retroclination of the upper incisors would occur, or

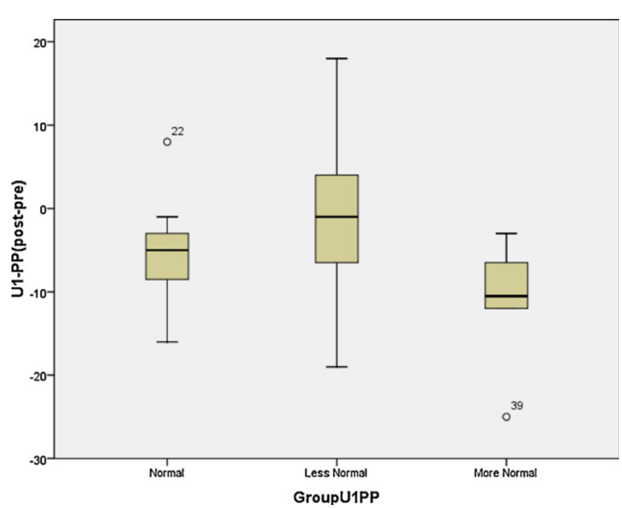

Fig. 9. Box plot of the change in U1-PP angle before and after surgery.

Table 8. Present data and previous study results.

Study	Kind of appliance	Result	Comparison with the present study
Haas[11]	RME (tooth-borne device)	Downward and forward movement of the maxilla	Similar
Davis and Kronman[7]	RME (tooth-borne device)	Downward and forward movement of the maxilla	Similar
		Mandibular backward movement	In the present study the SNB increased but is not significant
Wertz[28]	RME (tooth-borne device)	Downward and forward movement of the maxilla, incisor retroclination	Similar
Da silva filho et al.[6]	RME (tooth-borne device)	No significant alterations of the maxilla in the anteroposterior position	In the present study we did not measure linear changes
		Downward and backward rotation in the palatal plane, which can result in increasing facial height	Similar
		Mandibular downward and backward rotation	In the present study the SNB increased but is not significant
Chung et al.[5]	HAAS appliance	Anterior and vertical movement of the maxillary halves, which were not significance	Downward movement of maxilla in this study is significant
		Incisor retroclination	Similar
Sandikcioglu and Hazar[24]	RME (tooth-borne device)	Incisor retroclination	Similar
Akkaya et al.[1]	RME (tooth-borne device)	Incisor retroclination	Similar
Lagravère et al.[13]	SRPE (tooth-borne device)	Vertical and sagittal skeletal changes were nil or not clinically significant	Not similar
			Downward movement of maxilla in this study is significant
Lagravère et al.[12]	Tooth borne and bone borne appliances	No significant anterior skeletal or dental movement	In the present study we did not measure linear changes
			Retroclination of the upper incisors were significant in the present study
Neubert et al.[17]	Biedermann-Hyrax-screw	No vertical or sagittal maxillary displacement	Not similar
			Downward movement of maxilla in this study is significant
Gilon et al.[9]	SRPE (tooth-borne device)	Significant anterior rotation of the palatal plane	Similar
		Decrease of the SNB angle	In the present study the SNB increased but is not significant
Davis and Kronman[7]	RME (tooth-borne device)	Increasing SN-PP (palatal plane) angle	Similar
Chung and Font[4]	RME (tooth-borne device)	Both ANS and PNS moved significantly downward	Not similar
		Downward and backward rotation of the mandible	Not similar
Basciftci and Karaman[3]	RME (tooth-borne device)	Downward and forward movement of the maxilla	Similar
		Mandibular backward movement	In the present study the SNB increased but is not significant
Sarver and Johnston[25]	RME (tooth-borne device)	Forward movement of the maxilla	In the present study we did not measure linear changes
Monini et al.[16]	RME (tooth-borne device)	Mandibular counter-clockwise rotation and reduction of facial height	–
Günbay et al.[10]	TPD (bone-borne)	Increasing of Sn_ Go-Gn angle and SNA and ANB	Similar
		Decreasing SNB	In the present study we did not measure linear changes

would have been counteracted by the orthodontic treatment with fixed appliances. A decrease of U1-SN can be useful in class III patients, but most patients in this study had class II occlusion and these changes are not desirable since it diminishes overjet. In 7 patients (14%), the authors had to modify the primary treatment plan because of undesirable changes in overjet (negative overjet) necessitating an additional Le Fort I advancement in the treatment plan. It is unclear why these changes in inclination of upper incisors occur, despite of orthodontic efforts. The retrospective nature of the present study allowed only a limited number of variables to be examined. Of clinical interest is the significant correlation between the pre-treatment inclination of the upper incisors and the amount of subsequent change. Steeply inclined incisors will not change much in inclination, whereas upper incisors in proclination will change much more.

After SARPE with bone-borne appliances and subsequent orthodontic alignment in patients scheduled for Le Fort I, BSSO, or bimaxillary osteotomies, this study supports the finding that the expanded maxilla has a clockwise rotation with an SNA angle increase ($1.60^\circ \pm 2.57$) ($P < 0.05$) and PP-SN plane angle increase (mean $0.94^\circ \pm 2.13$) ($P < 0.05$). The results also showed than the initial inclination of the upper incisors will decrease (the higher the inclination, the more the decrease) as follows: U1-SN plane angle ($-4.82^\circ \pm 8.94$) ($P < 0.05$) and U1-PP plane angle ($-3.86^\circ \pm 8.56$) ($P < 0.05$). The fact that the maxilla rotates clockwise explains why the decrease of the angle of the upper incisor to SN is greater than the decrease of the angle of the upper incisor to palatal plane.

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Conflict of interest

None declared.

Ethical approval

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