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# Bone changes on lateral cephalograms and CBCT during treatment of maxillary narrowing using palatal osteodistraction with bone-anchored appliances

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A B S T R A C T

The most common problem in surgical and orthodontic treatment involves abnormal transverse dimension of the maxilla. Behaviour of the facial skeleton in its anterior-posterior dimension during treatment of maxillary narrowing using surgical assist is interesting to observe.

Assessment of bone changes of the maxillary location assessed on lateral cephalograms and CBCT during surgically assisted maxillary expansion with bone-anchored appliances.

The analysed material included documentation of 78 patients, the mean age of 16.86±2.65, treated with transverse maxillary distraction using a bone-anchored appliance. The software (Dolphin Imaging) was used to measure parameters on lateral cephalograms.

Results obtained analysis of correlation between planes, angles and diameters between teeth before and after treatment. Simple Regression - SNA vs. SN-OCCL change of the anterior height with regard to changes in the occlusal angle refer to the opening and dropping of the maxilla in the anterior section.

Simple Regression - SNA vs. S-PNS-ANS describe changes in the anterior section such as opening of the S-PNS-ANS angle, and in a correlation with the SNA angle opening it indicates maxillary dropping and protrusion.

Dropping and protrusion of the maxilla can be observed during surgically assisted maxillary expansion with bone-anchored appliances. Maxillary anterior movement may depend on a surgical procedure.



## 1. Introduction

The most common problem observed in surgical-orthodontic and orthodontic treatment of facial and occlusal defects involves abnormal transverse dimension of the maxilla (Bell and Epker, 1976). Symptoms of such a deformation include posterior crossbite, high palate, crowding and inclination of teeth in the anterior section. This defect may be present as an isolated defect or combined with other facial and occlusal class II or III deformations (Betts et al., 1995).

Many authors have been trying to prepare a management protocol to correct this defect. It is possible to affect the transverse dimension during the patient's growth using such orthodontic methods as slow and rapid maxillary expansion. It is an orthodontic domain (Handelman et al., 2000), When the facial skeleton is mature it is not possible to expand the transverse dimension using orthopaedic appliances only. Surgical and orthodontic collaboration is necessary as it involves cutting the maxillary bones and expanding the skeletal maxillary base as a result of distraction osteogenesis using tooth- or bone-anchored appliances (Verstraaten et al., 2010).

The age when this type of treatment should be applied has not been agreed on (Handelman et al., 2000; Cao et al., 2009). So far, the optimum timepoint when the maxilla ossification resulting in lack of possibility of its transverse expansion takes place has not been determined (Cohen, 1993).

When transverse expansion with orthopaedic appliances is used too late, the following complications may occur: abnormal tooth position – inclination, damage to the supporting structures or even facial pain and damage to the cranial base area (Ramieri et al., 2005; Kilic et al., 2008; Holberg et al., 2007).

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On the other hand, indications for maxillary expansion have been defined relatively well, although there are some controversies in this subject as well. They depend on the preferences of the orthodontist and the treating team (Northway, 2011; Chrcanovic et al., 2009).

It is usually accepted that a transverse deficit of 4–5 mm is an indication to apply surgically assisted maxillary expansion. Additionally, the shape of the hard palate and the occlusal plane are decisive factors with regard to the introduction of surgical treatment (Rana et al., 2013).

A surgical procedure alone may also be different depending on the site of osteotomy and maxillary release (Pereira et al., 2012; Reinbacher et al., 2013). Appliances used for maxillary expansion may be tooth- or bone-anchored. In 1999 Mommaertes was the first one to introduce a bone-anchored distractor (Mommaerts, 1999).

This appliance is associated with numerous benefits. Changes in the transverse maxillary structure resulting from its expansion are well understood and documented (Seeberger et al., 2011). In this context it is interesting to see that the bone structures of the facial skeleton are maintained in the anterior and posterior dimension during surgically-assisted maxillary expansion.

### 1.1. Aim

Assessment of bone changes of the maxillary location assessed on lateral cephalograms and CBCT during surgically assisted maxillary expansion (SARME) with bone-anchored appliances.

## 2. Material and methods

The Bioethics Committee approved the study with the opinion no. 26/2013/V. The analysed material included documentation of 78 patients aged between 12 and 23 years, the mean age of 16.86 ± 2.65, treated with transverse maxillary distraction using a bone-anchored appliance.

### 2.1. Patients

Patients with maxillary narrowing with a deficit of the transverse dimension >4 mm in whom it was necessary to perform a surgical intervention were considered eligible for treatment.

### 2.2. Treatment

A surgical procedure included a maxillary osteotomy type Le Fort I (LFI) through the posterior maxillary surface, the zygomatic alveolar crest, anterior wall of the maxillary sinus and edge of the piriform aperture; a midline osteotomy between the roots of central incisors was performed. The junction of the pterygoid process of the maxilla behind the maxillary tubercle was released. At the same time, the nasal septum was not separated from the bottom of the nasal cavity (Fig. 1). On the palatal surface of the maxilla a T-shaped incision was made – the mucous membrane and periosteum were cut between the first molar and the second premolar resulting in bone exposure. Then, the Titamed Smile Distractor with two screws and sleeves supported on the palatal processes of the maxilla with platforms that were mounted with self-tapping screws was placed; the distractor is opened via a stretching-screw mechanism.

Distraction was performed according to the following protocol:

1. Procedure and latency period: 5–7 days
2. Distraction period: 2 × daily 1/3 of a rotation (approx. 0.6 mm)
3. Consolidation period between 3 and 6 months

The appliance was activated 7 days after the procedure. Distraction was performed according to the following protocol: two rotations – one in the morning and one in the evening, and one rotation was 0.25 mm.

### 2.3. Measurements

The same calibrated operator performed all measurements, and repeated all measurements 1 month later.

Measurements were performed prior to the procedure and 3 months after the completion of osteodistraction, when the appliance was removed.

Imaging tests were performed with the Carestream Dental LLC CS 9300 System, with patients in the same, repetitive positions.

Changes were measured in the periods T1-T2, where T1 indicates prior to the procedure, and T2 indicates 3 months after the appliance had been blocked.

Using gypsum models, measurements in millimetres (mm) were performed between points on the cusp tips of the canines (3-3), on

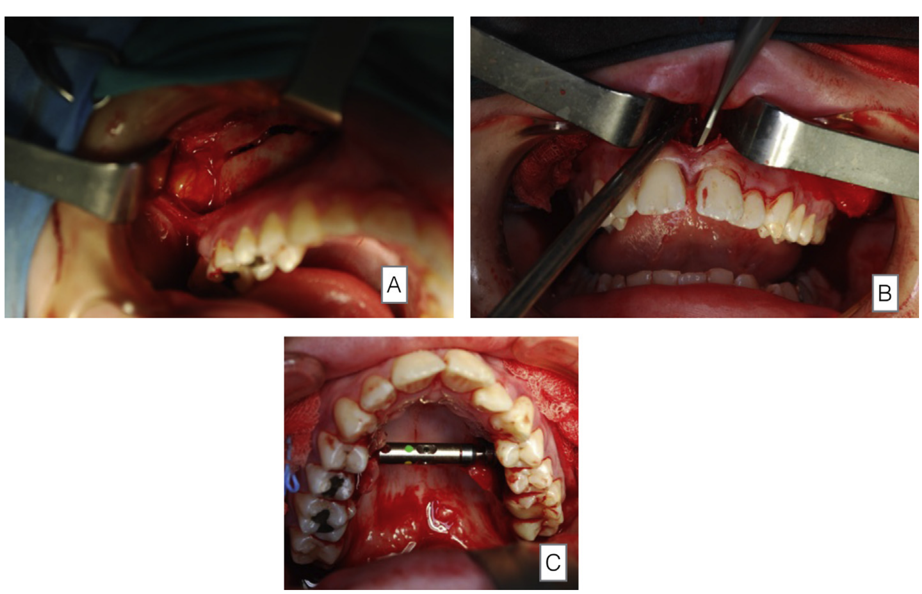


**Fig. 1.** Operation picture A – osteotomy line, B – midline osteotomy, C- distractor in situ.

the buccal cusp tips of the first maxillary premolars (4-4), on the cusp tips of the first maxillary molars.

The software (Dolphin Imaging 11.7, USA) was used to measure parameters on lateral cephalograms after appropriate craniometric points and planes had been marked. Points: A,N,S,B, ANS, PNS (Table 2). Planes: Frankfurt – through the orbitale and porion points, Occlusal (OCCL) – the plane marked by three points: incisal point and points on distobuccal cusps of the second lower molars/ bilaterally/

The following were measured on lateral radiograms of the skull (Fig. 2):

Distances in mm N-ANS – anterior section, S-PNS – posterior section.

Angles: anterior angles describe changes in the anterior section such as maxillary protrusion.

1. A-N-B 2. S-N-A 3. S-N-B 4. S-N-ANS 5. S-PNS-ANS.

Posterior angles 6. S-N-PNS – describes maxillary dropping in the posterior section 7. SN-OCCL – describes changes of the inclination of the occlusal plane.

The following were assessed on CBCT (Fig. 3):

PA-nosefloor, the bottom of the base of the nose, namely a distance between points located the most laterally on the internal bone surface of the nasal cavity (mm) in a scan at the level of the first maxillary molars.

CT_6-6 – distance between palatal cusps of the first maxillary molars.

CT_6-6_palat_plate distance between the skeletal margins from the palatal side of the first maxillary molars.

CT_palet_H palate height measured at the level of the first maxillary molars as a perpendicular line from the point on the apex of the hard palate to the line between palatal cusps of the first maxillary molars (Fig. 3).

**Table 1**
The mean range of changes in angles and distances.

| Parameters | Pre-treatment | Post-treatment | Significance |
|---|---|---|---|
| S-N-PNS | 39.54 ± 4.77 | 40.75 ± 3.46 | P = 0.133 |
| S-PNS-ANS | 113.53 ± 4.95 | 114.05 ± 5.21 | P = 0.521 |
| S-N-ANS | 7.26 ± 5.78 | 7.05 ± 4.09 | P = 0.916 |
| SN-OCL | 16.67 ± 5.91 | 16.35 ± 4.58 | P = 0.710 |
| ANB | −0.75 ± 4.47 | 0.48 ± 4.04 | P = 0.074 |
| SNA | 82.52 ± 5.69 | 81.28 ± 4.19 | P = 0.124 |
| SNB | 82.05 ± 5.23 | 81.60 ± 5.06 | P = 0.586 |
| **S-PNS** | 47.42 ± 4.69 | 47.87 ± 4.48 | P = 0.548 |
| **N-ANS** | 50.72 ± 4.24 | 51.32 ± 4.45 | P = 0.405 |
| *PA-nosefloor* | 24.49 ± 4.14 | 25.72 ± 4.08 | P = 0.063 |
| *CT_6-6* | 36.94 ± 3.47 | 41.77 ± 4.26 | **P < 0.001** |
| *CT_6-6_palat_plate* | 31.44 ± 3.06 | 36.25 ± 3.92 | **P < 0.001** |
| *CT_palet_H* | 14.32 ± 2.41 | 13.38 ± 2.67 | P = 0.063 |

Bold defines mean changes in the angles and distances that demonstrate the maxillary movement to the bottom and to the front are not statistically significant.

**Table 2**
Definitions of cephalometric points.

| | |
|---|---|
| A | - the most deeply positioned point on the bone curvature between the anterior nasal spine and the maxillary alveolar process |
| B | - the most deeply positioned point in the midline between infradentale and pogonion |
| N | - the most anterior point on the nasocranial suture in the midline |
| S | - the point in the middle of the sella turcica |
| ANS | - the anterior nasal spine, the bone top of the anterior nasal spine located in the midline |
| PNS | - the posterior nasal spine positioned on the crossing of the anterior wall of the pterygopalatine fossa and nasal cavity bottom |
| OCCL | - the plane marked by three points: incisal point and points on distobuccal cusps of the second lower molars /bilaterally/ |

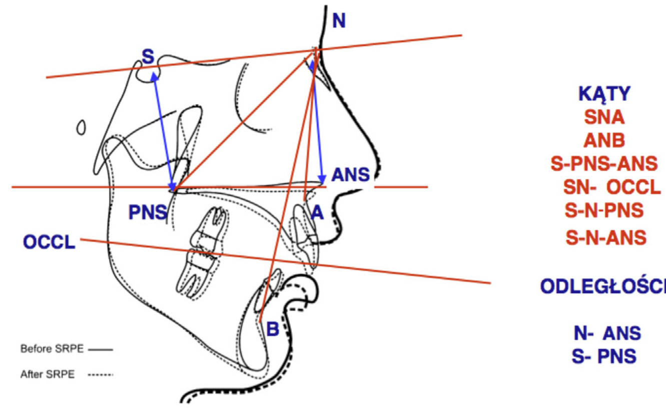


**Fig. 2.** Measurements.

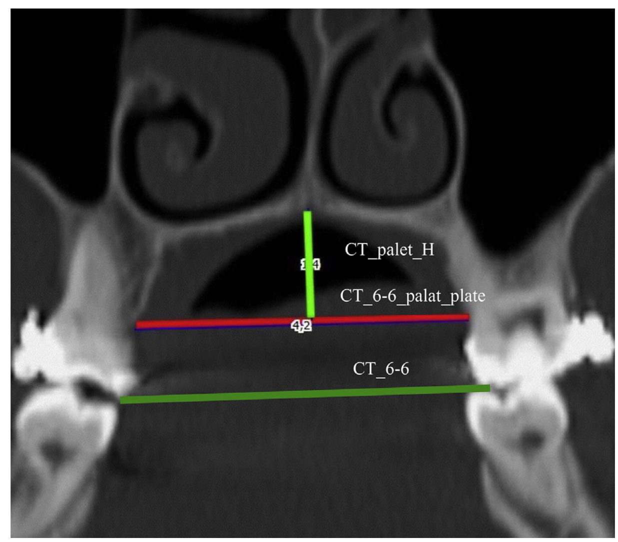


**Fig. 3.** CBCT image.

### 2.4. Statistical analysis

Statistical analysis was performed in Statgraphics Centurion XVI (StatPointTechnologies. Inc., USA). One-way analysis of variance was applied to investigate data of treated patients. Pre-osteotomy data and post-osteotomy results were established as factor hypothetically influencing data. Analysis of regression was used to check the relationship between cephalometric measurements and airway volume, and change in relationship of each other measured parameters. The level of significance was established as $p < 0.05$.

## 3. Results

The analysis of data from 78 patients before and after the procedure was performed with the Statgraphics Centurion XVI (StatPointTechnologies. Inc., USA). Individual data were compared.

Using gypsum models, changes were measured in the periods T1-T2, where T1 indicates prior to the procedure, and T2 indicates 3 months after the appliance had been blocked (Fig. 3).

The intercanine dimension, between the cusp tips of the maxillary canines T1-T2_3-3 was 7.68 ± 3.78.

The anterior arch width, between the palatal cusp tips of the first maxillary premolars T1-T2_4-4 was 8.26 ± 3.08.

The posterior arch width, between the palatal cusp tips of the first maxillary premolars T1-T2_6-6 was 5.98 ± 2.60.

The mean range of changes in angles and distances was also measured, and a correlation between individual variables – angles and distances was estimated to determine their mutual relationships and correlations (Table 1).

Mutual correlation of changes in SNA and ANB before and after the procedure:

A change in the SNA angle does not significantly affect a change in the ANB, before the procedure the correlation is stronger (Fig. 7).

Simple Regression SNA vs. S-N-PNS before the procedure was P-Value 0.0004, after the procedure was P-Value 0.2953 (Fig. 8).

Simple Regression S-N-PNS vs. SNA before the procedure P-Value 0.8757, after the procedure was P-Value 0.0023 (Fig. 9).

The relation of S-N-PNS to SNA [$R2 = 8.9\%$, $p < 0.01$] becomes stronger post-operationally [$R2 = 11.9\%$, $p < 0.005$].

This means that along with an increase in the S-N-A anterior angle, the S-N-PNS posterior angle increases significantly. Namely, the maxilla moves anteriorly and drops posteriorly; however, the mean values of changes in individual elements do not demonstrate statistical significance: S-PNS-ANS - P = 0.521, SNA - P = 0.124 (Fig. 10).

Simple Regression - SN-OCCL vs. N-ANS, Pre op P-Value 0.8757, post op P-Value 0.3482.

Effects of changes in the occlusal angle on the maxillary anterior section:

There is no correlation between a change in the occlusal angle on the maxillary anterior section, namely, treatment does not affect this correlation (Fig. 11).

Simple Regression - SNA vs. N-ANS, pre P-Value 0.6321 post P-Value 0.6144.

There is no correlation between a change in the SNA angle and the N-ANS anterior section, namely, a correlation of variables does not change due to treatment (Fig. 12).

Simple Regression - N-ANS vs. S-PNS-ANS, pre op P-Value 0.9444, post op P-Value 0.1134.

Along with an increase in the N-ANS distance after the procedure there is mild opening of the angle, without statistical significance.

Simple Regression - SN-OCCL _pre vs. S-PNS_pre P-Value 0.0015, post P-Value 0.0031 (Fig. 13)

A change in the occlusal angle with regard to the posterior facial section visible in a post-operative analysis is statistically significant with regard to the slope of the angle of the occlusal plane and the

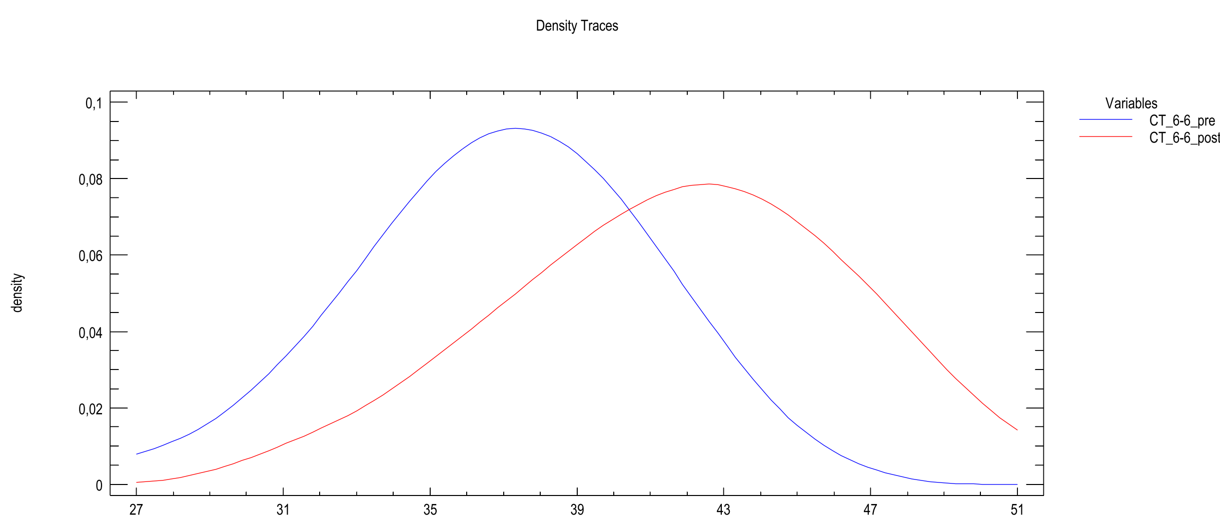


**Fig. 4.** CT_6-6-distance between palatal cusps of the first maxillary molars.

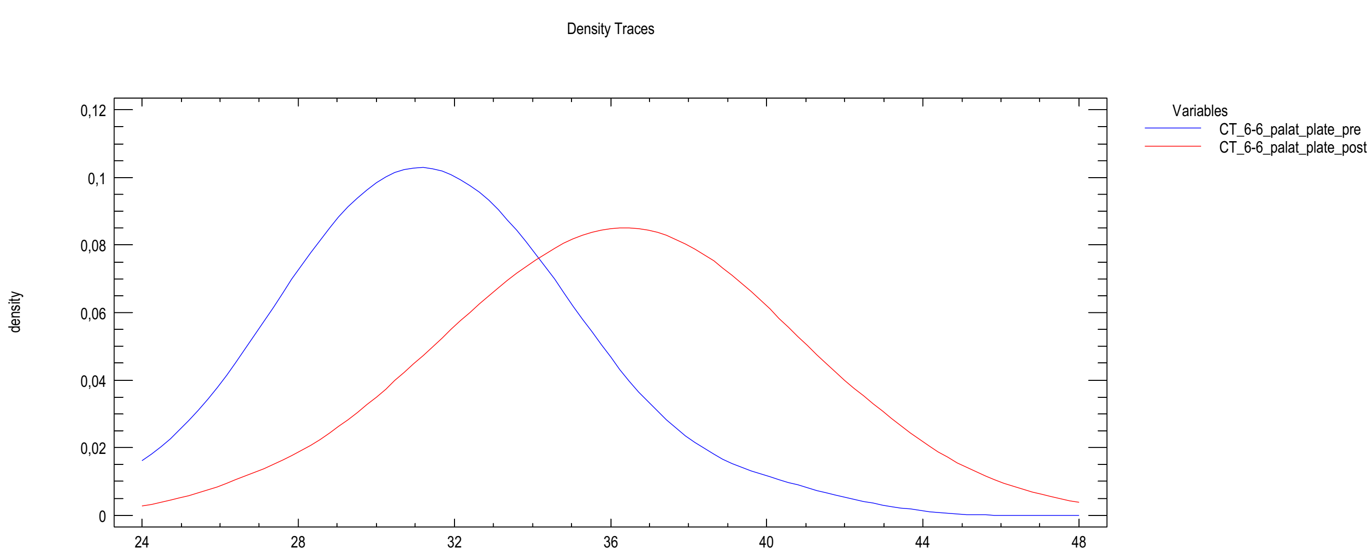


**Fig. 5.** Changes CT_6-6_palat_plate distance between the skeletal margins from the palatal side of the first maxillary molars.

posterior section. A correlation of variables can be deduced; however, results of mean changes do not reveal statistical significance S-PNS- P = 0.548, SN-OCL- P = 0.710.

Simple Regression - S-PNS_ vs. S-PNS-ANS, pre op P-Value 0.1828, post op P-Value 0.3192.

The change in the posterior section does not affect the angle, namely the anterior maxillary opening, and it is as expected (Fig. 14).

Simple Regression – S-PNS vs. N-ANS changes in the length of the anterior and posterior sections are straightly proportional to each other, P-Value is 0.0000 (Fig. 15).

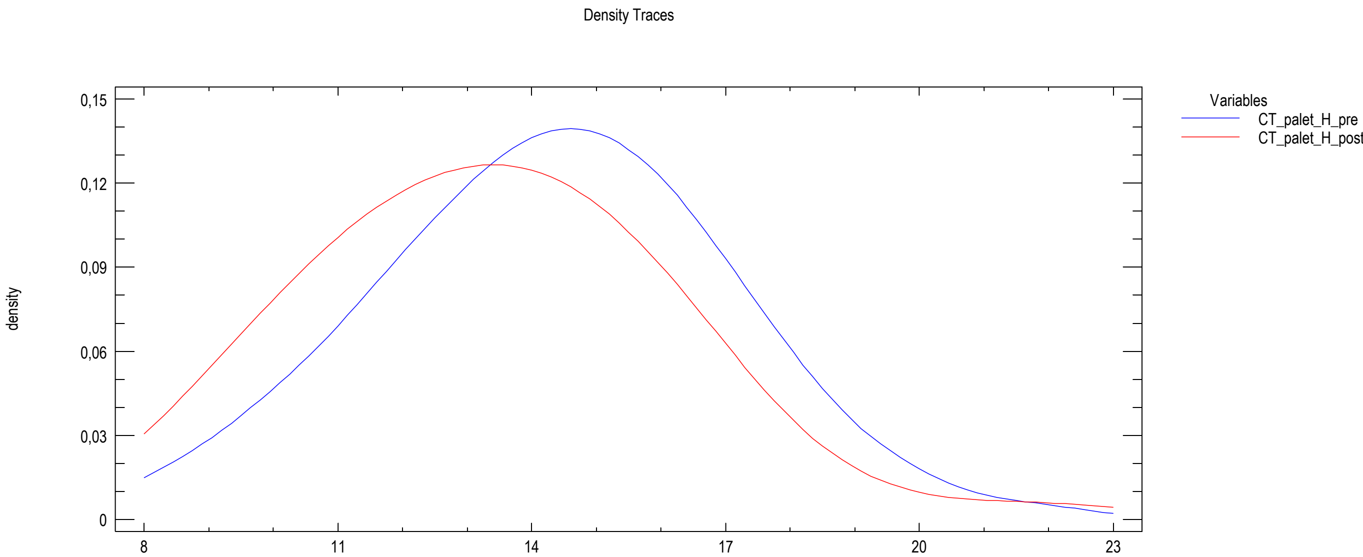


**Fig. 6.** CT_palet_H palate height measured at the level of the first maxillary molars.

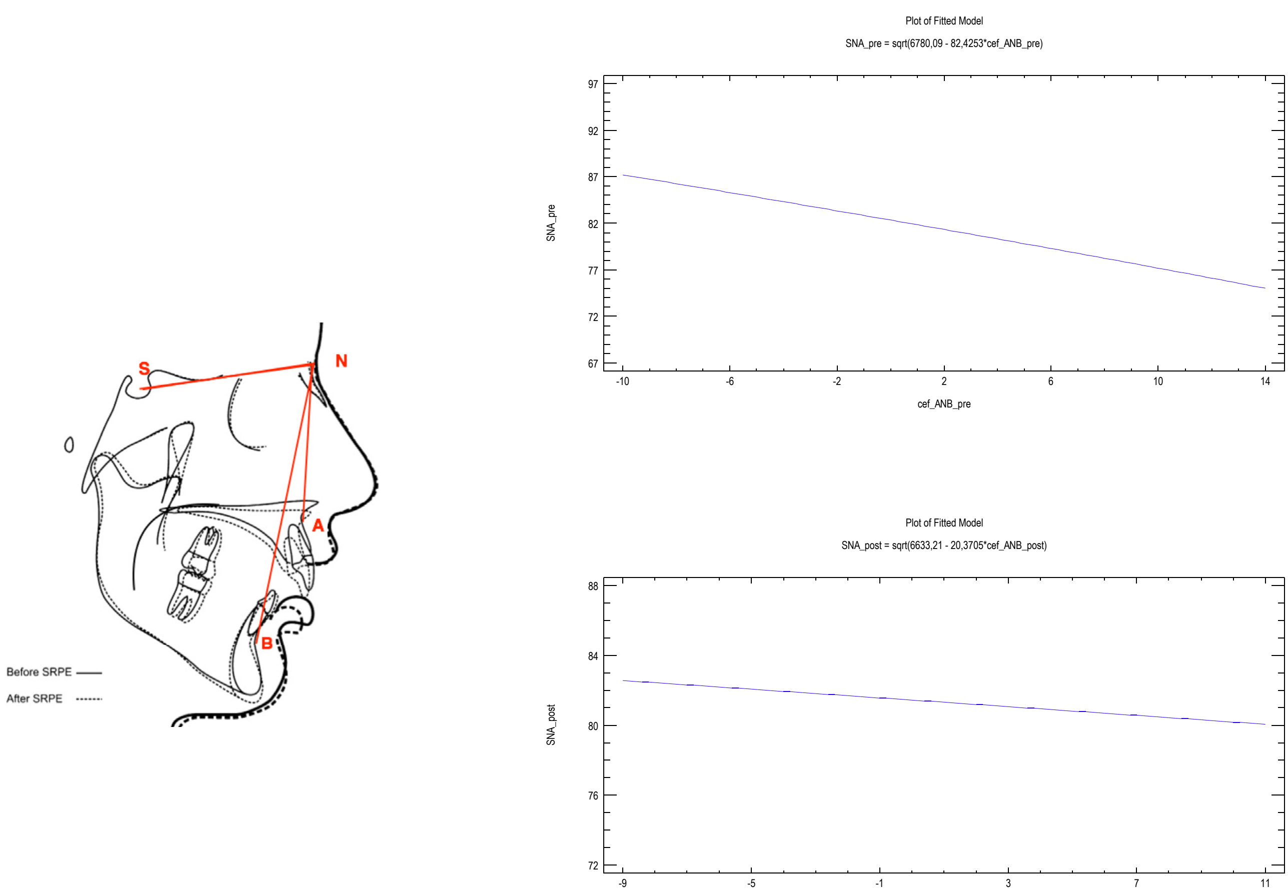


**Fig. 7.** A correlation of SNA and ANB variables before and after the procedure. A change in the SNA angle does not significantly affect a change in the ANB, before the procedure the correlation is stronger.

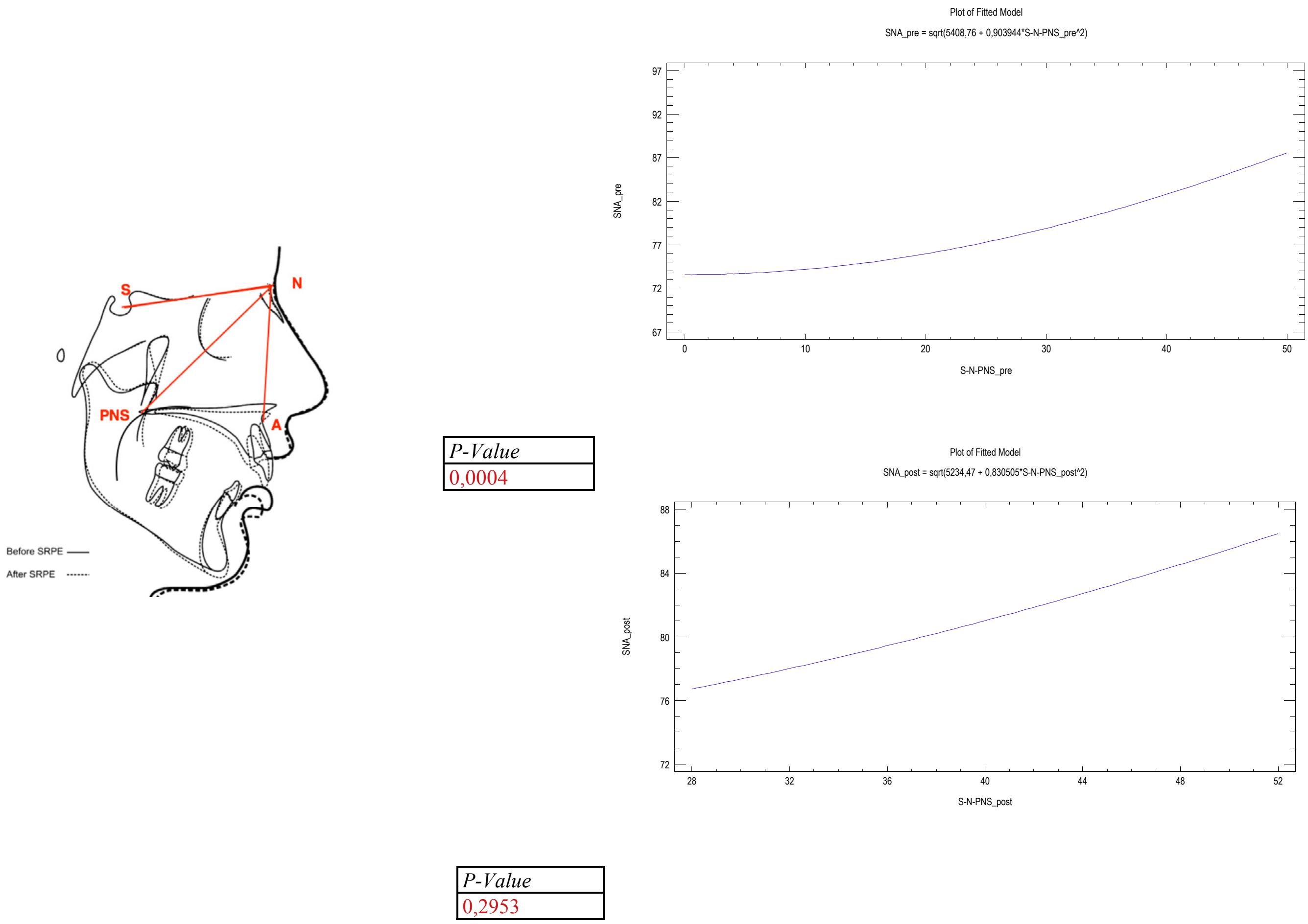


**Fig. 8.** Simple Regression – SNA vs. S-N-PNS.

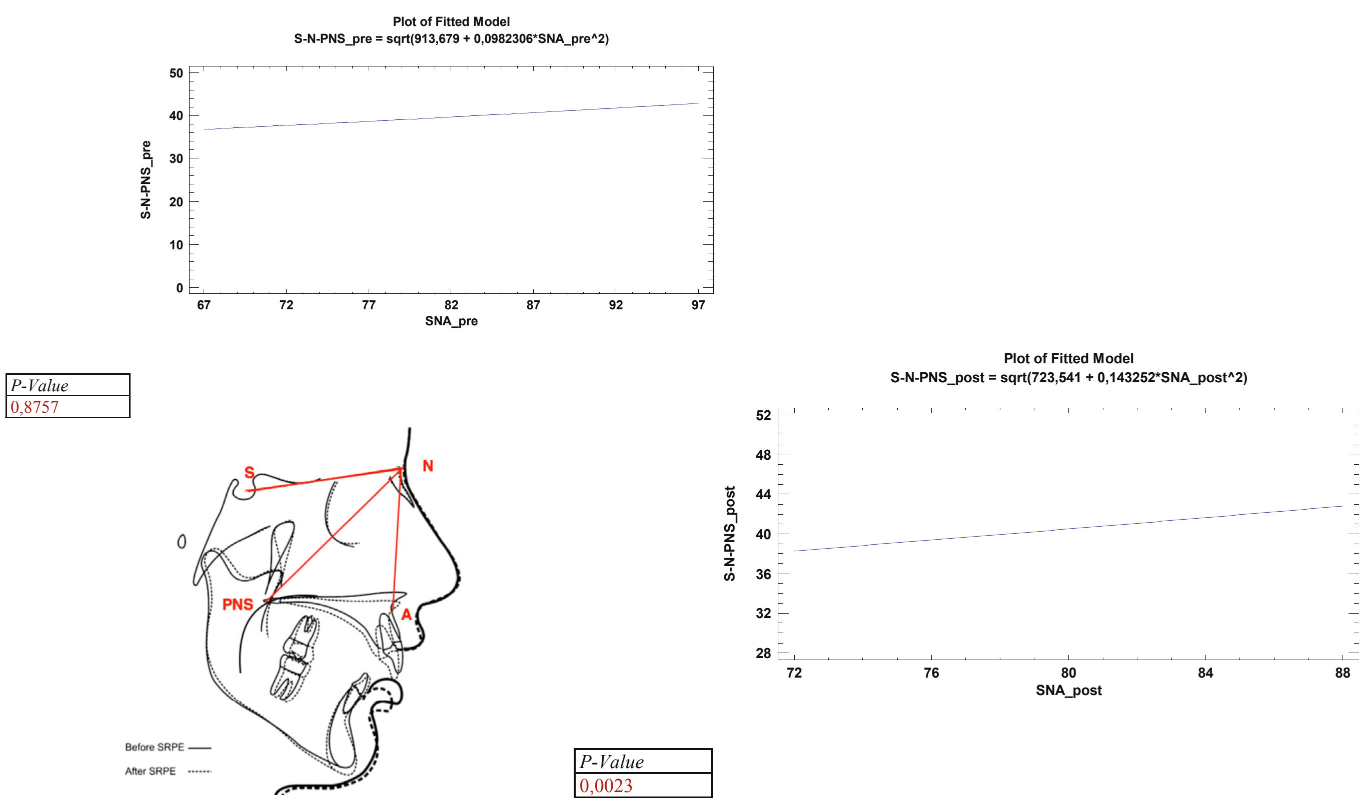


**Fig. 9.** Simple Regression – S-N-PNS vs. SNA The relation of S-N-PNS to SNA [p < 0.01] becomes stronger postoperatively [p < 0.005].

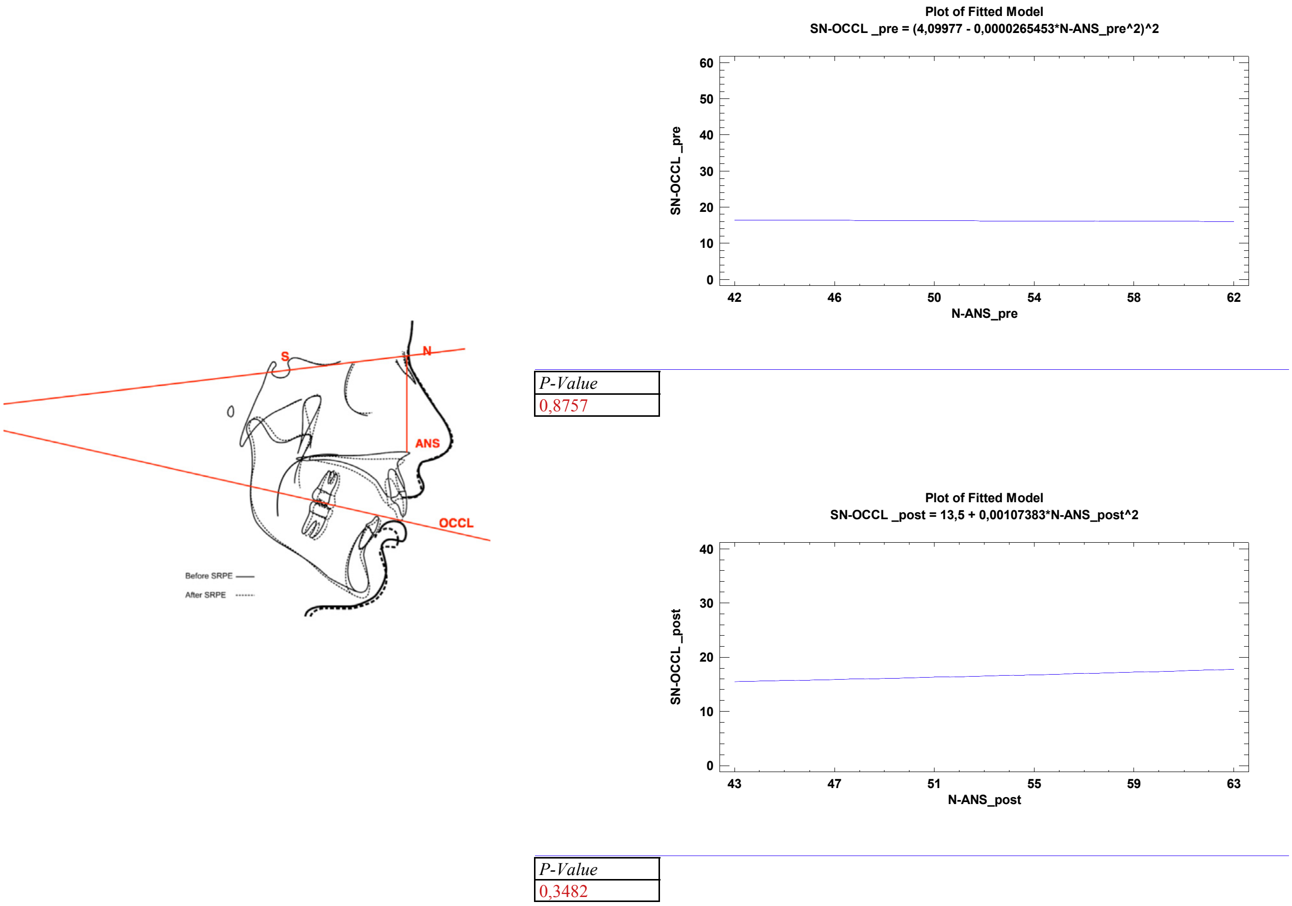


**Fig. 10.** Simple Regression – SN-OCCL _pre vs. N-ANS The effects of the changes in the occlusal angle on the maxillary anterior section.

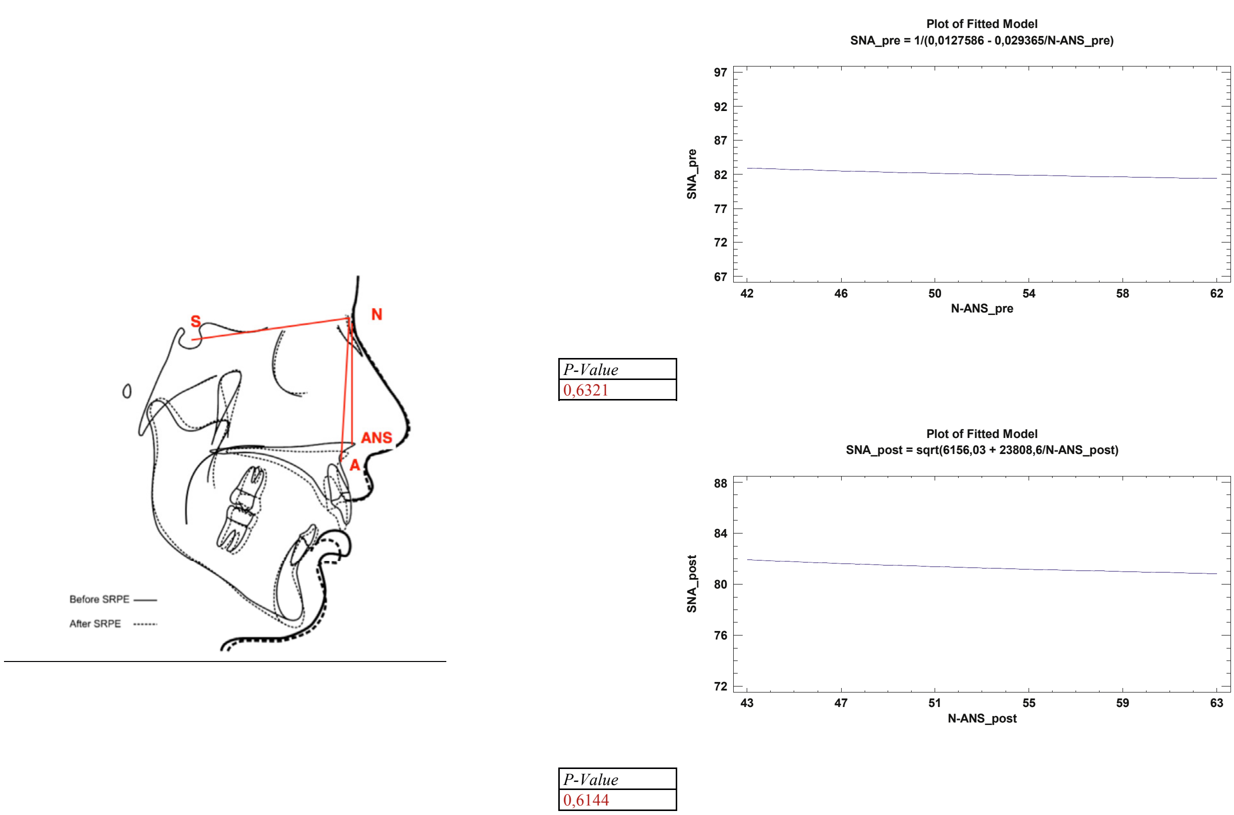


**Fig. 11.** Simple Regression – SNA_pre vs. N-ANS.

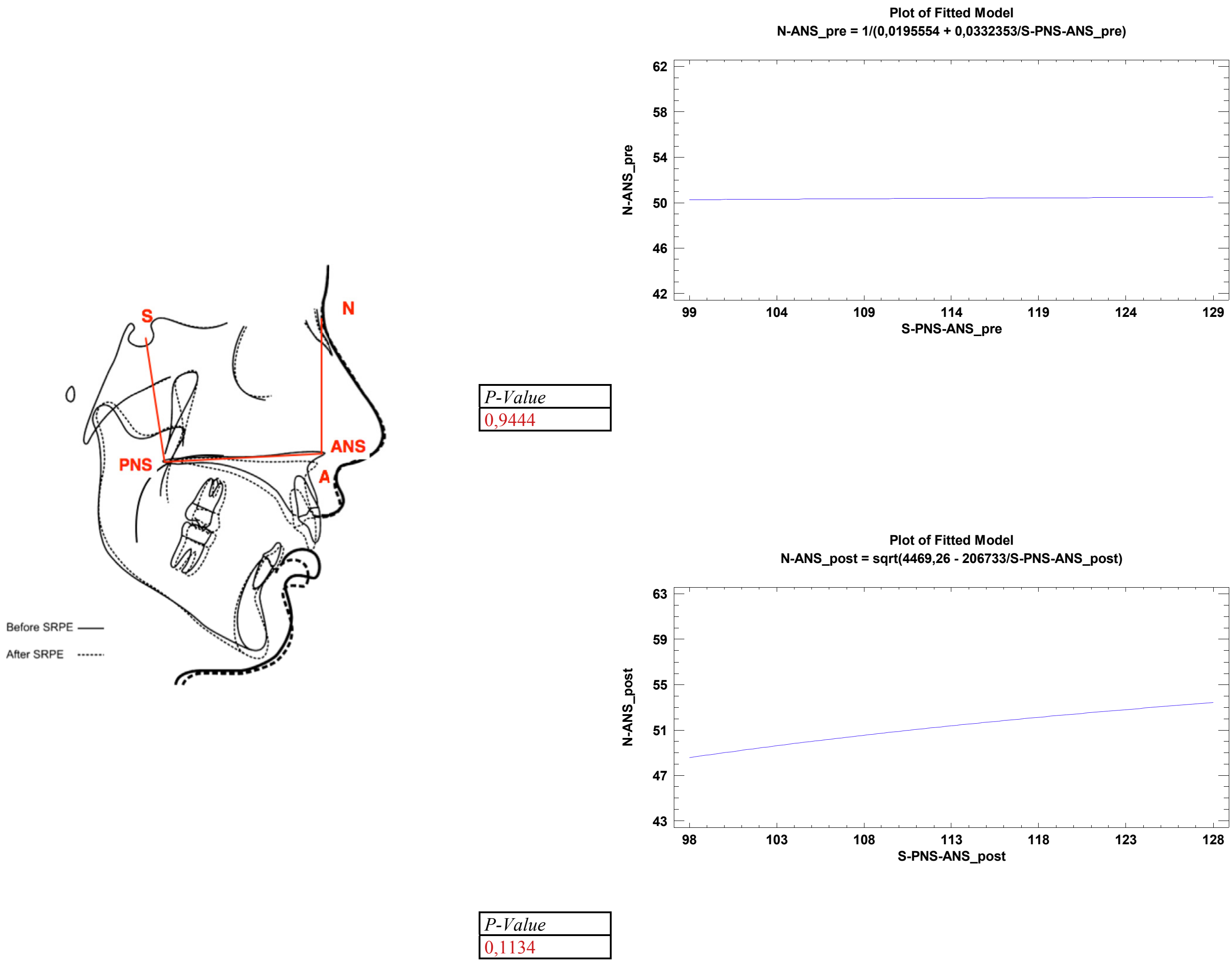


**Fig. 12.** Simple Regression – N-ANS_pre vs. S-PNS-ANS.

Simple Regression – SNA vs. SN-OCCL, pre operation P-Value 0.0217, post operation P-Value 0.0002 (Fig. 16)

Change in the SNA angle, namely maxillary protrusion with regard to changes in the occlusal angle, refer to the opening, dropping, and protrusion of the maxilla in the anterior section. There is postoperative statistical significance $p = 0.0002$. Therefore maxillary movement is observed (SNA) depending on changes in the occlusal angle. There is no statistical significance with regard to mean changes of the distance SNA- $P = 0.124$, SN-OCL- $P = 0.710$.

Simple Regression – SNA_ vs. S-PNS-ANS (Fig. 17) describes changes in the anterior section such as opening of the S-PNS-ANS angle, pre operation P-Value 0.0081, post operation P-Value 0.0023. In correlation with the opening of the SNA angle, it refers to maxillary dropping and protrusion. The relation of S-N-PNS to SNA [$R2 = 8.9\%$, $p < 0.01$] becomes stronger post-operationally [$R2 = 11.9\%$, $p < 0.005$]. It indicates anterior movement of the maxilla and dropping in the anterior section.

A correlation was found between a change in the SNA angle with an increased dimension between individual teeth:

Simple Regression – SNA_post vs. T1-T2_3-3.
Simple Regression – SNA_post vs. T1-T2_4-4.
Simple Regression – SNA_post vs. T1-T2_6-6.

A correlation was found between change in the SN-OCCL angle with an increased dimension between individual teeth:

Simple Regression – SN-OCCL _post vs. T1-T2_3-3.
Simple Regression – SN-OCCL _post vs. T1-T2_4-4.
Simple Regression – SN-OCCL _post vs. T1-T2_6-6.

## 4. Discussion

Changes during surgically assisted rapid maxillary expansion (SARME) have been assessed by many authors (Mossaz et al., 1992; Wriedt et al., 2001). Most frequently, the effects of the RME method are compared with the effects of SARME (Berretin-Felix et al., 2006).

During the RME procedure the pterygopalatine junction is not released, therefore tissue tension is higher compared to the SARME procedure, during which bone junctions around the maxilla are released (Glassman et al., 1984). Consequently, the force on the base of the skull is lower, because the maxilla is not connected with other bone structures that apply forces to the base of the skull (Holberg et al., 2007).

For these reasons and with regard to differences in the patients' age as well as treatment methods, it does not seem to be reasonable

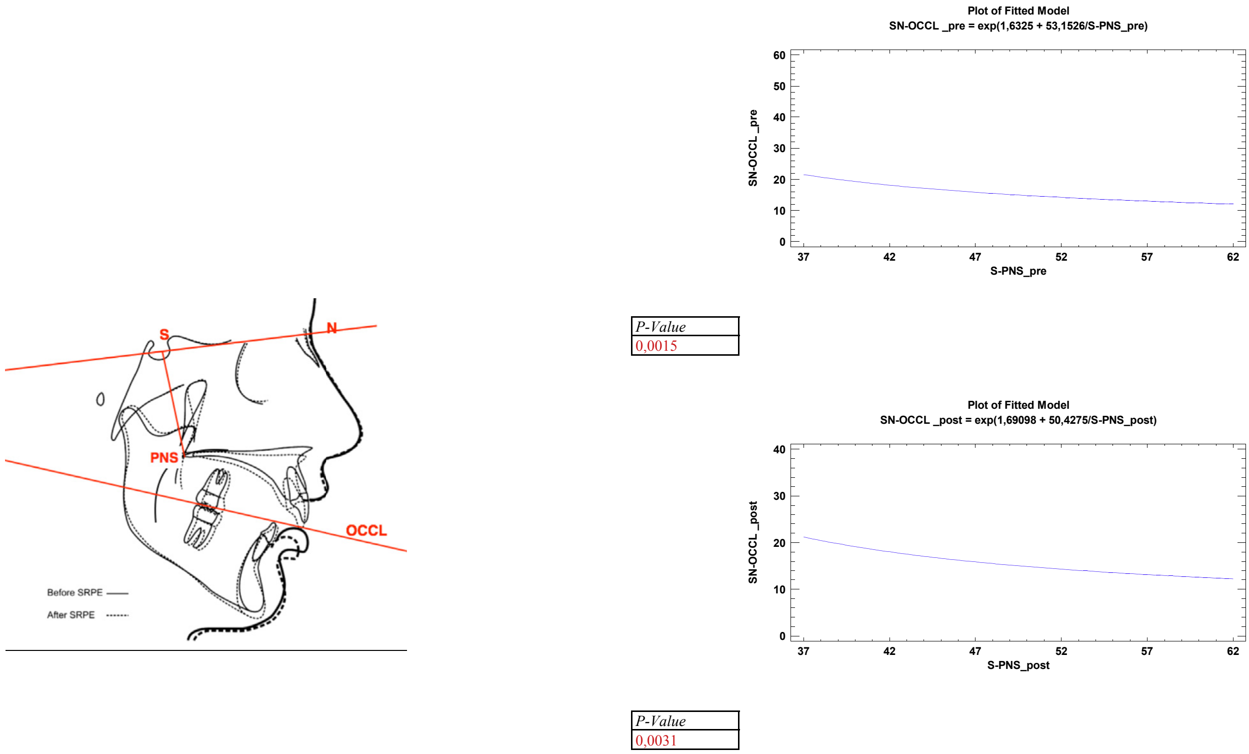


**Fig. 13.** Simple Regression – SN-OCCL _pre vs. S-PNS_pre P-Value 0.0015, post P-Value 0.0031.

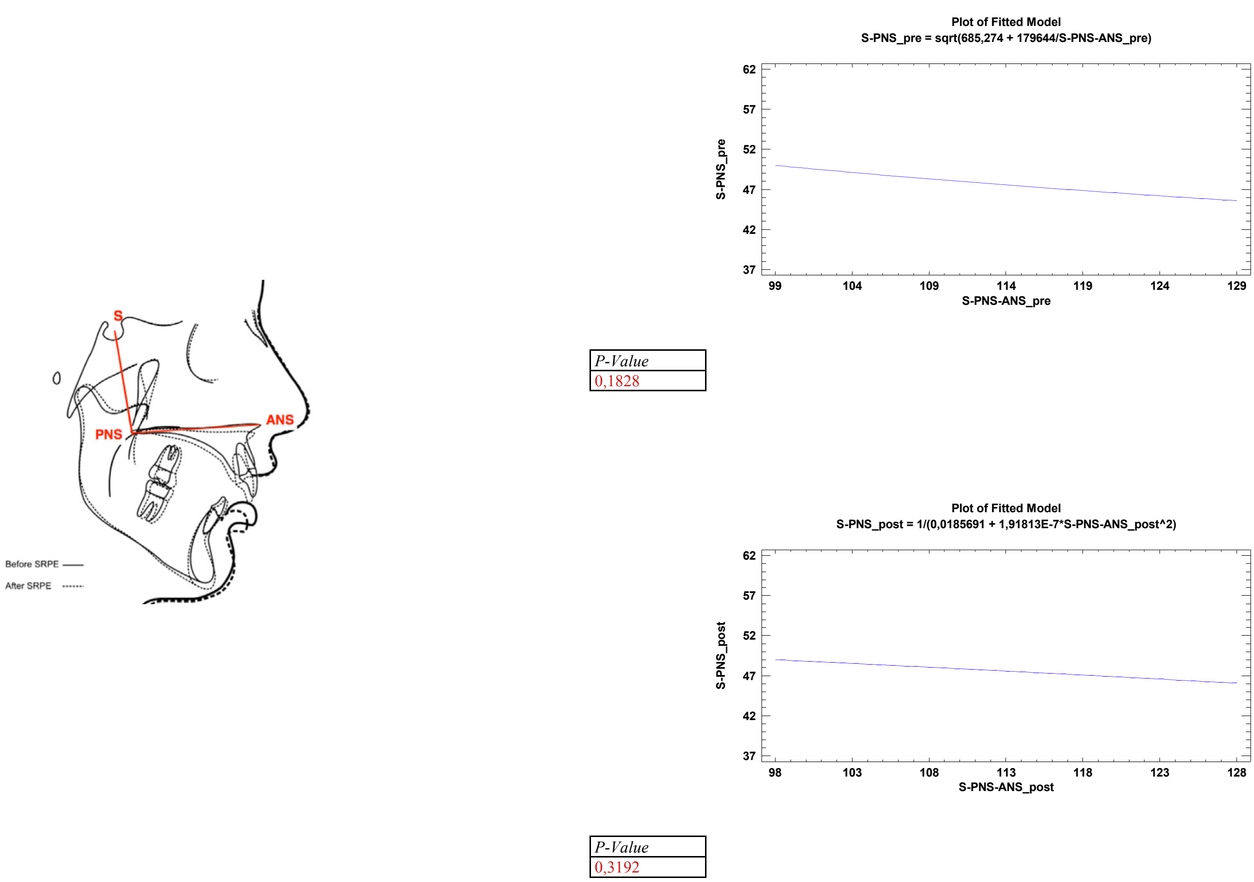


**Fig. 14.** Simple Regression – S-PNS_pre vs. S-PNS-ANS_pre.

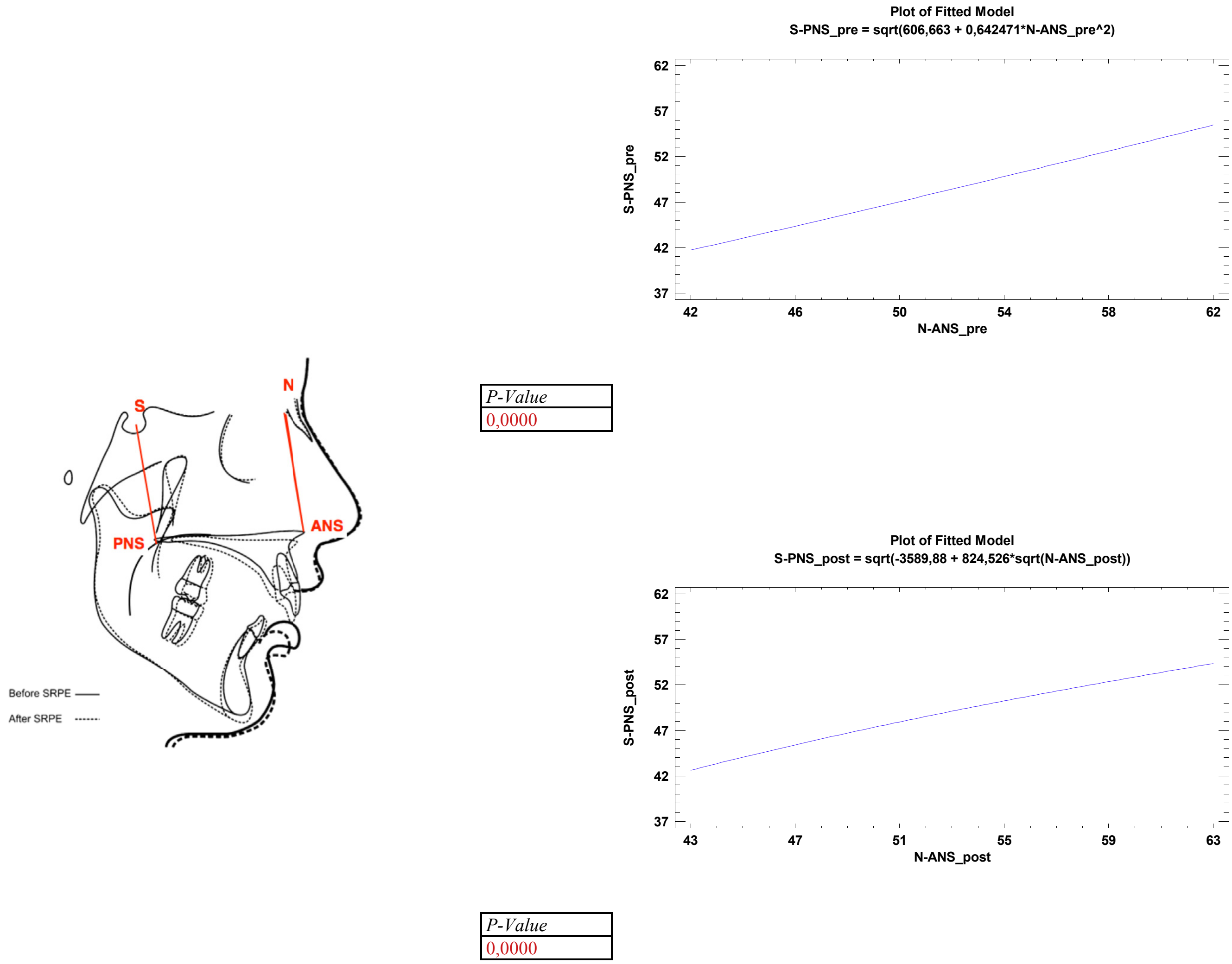


**Fig. 15.** Simple Regression – S-PNS vs. N-ANS B.

to compare both methods, although similar results are obtained. There are only a few articles available assessing anterior-posterior changes during SARME, and especially when bone anchorage was used. For this reason this study is very interesting and provides new material for a discussion on the use of SARME with bone anchorage. SARME is a well-described method to treat maxillary expansion. In this series complete maxillary Le Fort I osteotomy with release of all resistance sites, according to Momeaertes (Mommaerts, 1999) was used, and FEM studies confirm it is the best method to treat maxillary expansion effectively (Han et al., 2009; Holberg et al., 2007). A surgical procedure alone may also be different depending on the site of osteotomy and maxillary release. The use of LF I osteotomy alone, without releasing the pterygopalatine junction and without cutting the nasal septum, may affect the maxillary anterior movement. Additionally, the force and mobilisation range (complete or not complete) of osteotomy fragments may be of vital significance. However, the literature does not present any details in this regard.

The anterior maxillary movement may significantly affect the plan and effects of orthodontic treatment when SARME is used as an independent procedure prior to orthodontic treatment. Additionally, this effect should also be taken into account when planning a subsequent two-jaw procedure during positioning of the upper central incisors (Parhiz et al., 2011).

Reports regarding anterior-posterior changes on lateral cephalograms can be divided into reports on RME and SARME. However, RME does not require surgical intervention and data cannot be compared to SARME despite procedure similarities. Forces maintaining the maxilla during its expansion without surgical release are relatively high (Boryor et al., 2008) and result in anterior opening apart from protrusion. Authors who used RME report bite opening in half of the cases.

The majority of authors report movement of the maxilla toward the bottom, back and front, and it indicates bite opening and formation of an open bite in the anterior section, and as a result the facial vertical dimension is enlarged.

Parhiz A et al. (Gilon et al., 2000) studied changes in the maxillary position using surgically assisted maxillary expansion and observed that PP (palatal plane)- NA, SNA and ANB angles increase and U1– PP increase as well.

There are no static changes in the SNB and PP-Mand angles (angle between the palatal plane and mandibular plane) and SN – Mand (Parhiz et al., 2011). Report an increase in the PP-SN (from 5.62 to 6.56°), SNA (from 80.3° to 81.9°) and ANB (from 3.94° to 5°)

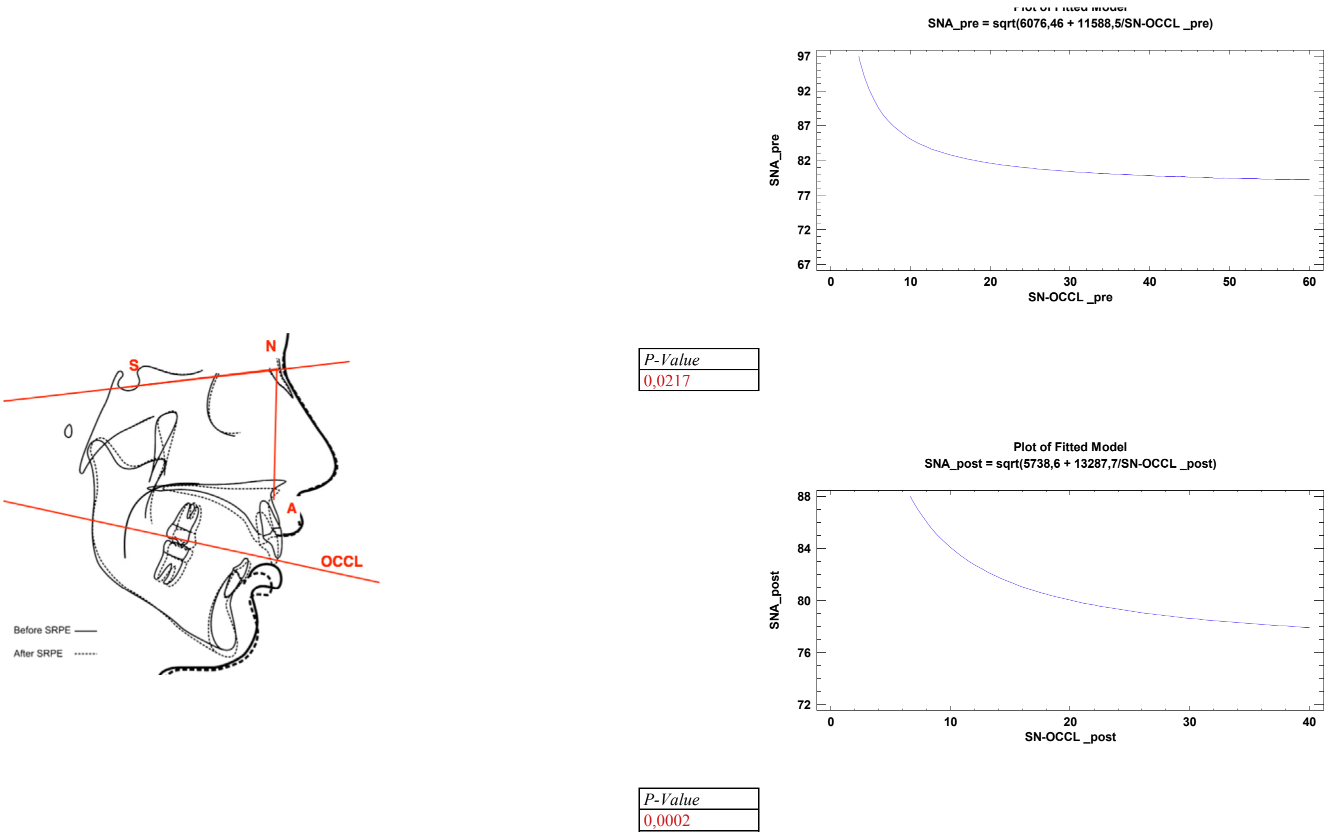


**Fig. 16.** Simple Regression – SNA vs. SN-OCCL change of the anterior height with regard to changes in the occlusal angle refer to the opening and dropping of the maxilla in the anterior section, there is postoperative statistical significance [$p = 0.0002$].

in their studies. Data confirm that the maxillary expansion is associated with movement - rotation toward the bottom. The scope of a change is associated with the scope of maxillary expansion.

Gilon et al., (2000) also use surgically assisted maxillary expansion with tooth-anchored appliances, and observe maxillary anterior movement and rotation as well as reduction of the SNB angle, and at the same time report maxillary expansion by 5 mm, and dilation of the nasal base by 4.4 mm. With regard to the vertical dimension, anterior rotation of the palatal base by 1.58 mm is observed.

Gunbay et al. use bone-anchored appliances and report an increase in the Sn _Go-Gn, SNA and SNB angle, and reduction of the SNB angle. The changes in the SNA, SNB, ANB, and SNGoGn measurements were found to be statistically significant. SNA increased by a mean of 1°. The SNGoGn angle had a mean increase of 1.15°, reflecting clockwise rotation of mandible, which resulted in a mean decrease of 0.75° in SNB angle. The ANB angle increased by a mean of 1.75° as a result of an increase in SNA angle and decrease in SNB angle. The changes in the Sella-nasion-point A, Sella-nasion-point B, Sella-nasion and gonion-gnasion angles were statistically significant (Günbay and Akay, 2008).

Goncalves Bretos (Bretos et al., 2007), measured SNA, SN – PP (palatal plane), Frankfurt plane – ANS, Frankfurt plane – PNS. There were changes in the SNA, and Frankfurt plane, NA, CF-A, CF-NA, Nperp-A, CF-A, Frankfurt horizontal plane-ANS, and Frankfurt horizontal plane-PNS. In all cases anterior and vertical maxillary movement was observed; however, in a group where the Hass appliance was used the movement was statistically significant. The authors divided patients into groups depending on what appliance was used for maxillary expansion: the Hass or Hyrax appliance. In the Hass group the SNA changed from 80.2 to 82.2 in the period immediately after distraction and to 81.8 in the late period 4 months after the end of distraction. Additionally, the sections between the Frankfurt plane and the PNS point that was projected vertically to this plane were measured, and there were changes from 24.4 to 23.9 mm at the end of the follow-up, namely maxillary shortening in the anterior section. In the Hyrax group there was a change in the SNA from 82° to 83.3° and distances between the Frankfurt plane and ANS from 23.4 mm to 23.6 mm, namely maxillary dropping in the anterior section.

According to the authors it is not possible to treat anterior maxillary disturbances based on the anterior movement during SARME. Sometimes it is necessary to use a facial mask in case of mild disturbances (Furquim et al., 2010). In more severe cases orthognathic treatment should be planned. There is movement in the vertical plane but it is not statistically significant.

Authors who observed lack of maxillary movement during surgically assisted maxillary expansion:

Chung CH et al. The objective of their work included studies on the vertical and horizontal movement of the maxilla caused by surgically assisted maxillary expansion. The study included 20 patients with the mean age of 25.6 years. Patients were treated with the Hass appliance with Le Fort I maxillary osteotomy. Cephalometric radiological imaging was performed before and after treatment, the SNA angle was measured, and the following measurements were taken: between the Frankfurt plane – N- A, S-N-maxillary palatal plane, and measurements of sections in millimetres – a distance from the A point to N and from S to N, on each cephalogram that was superimposed on the cranial base in case of examinations before and after treatment. Results demonstrate mild

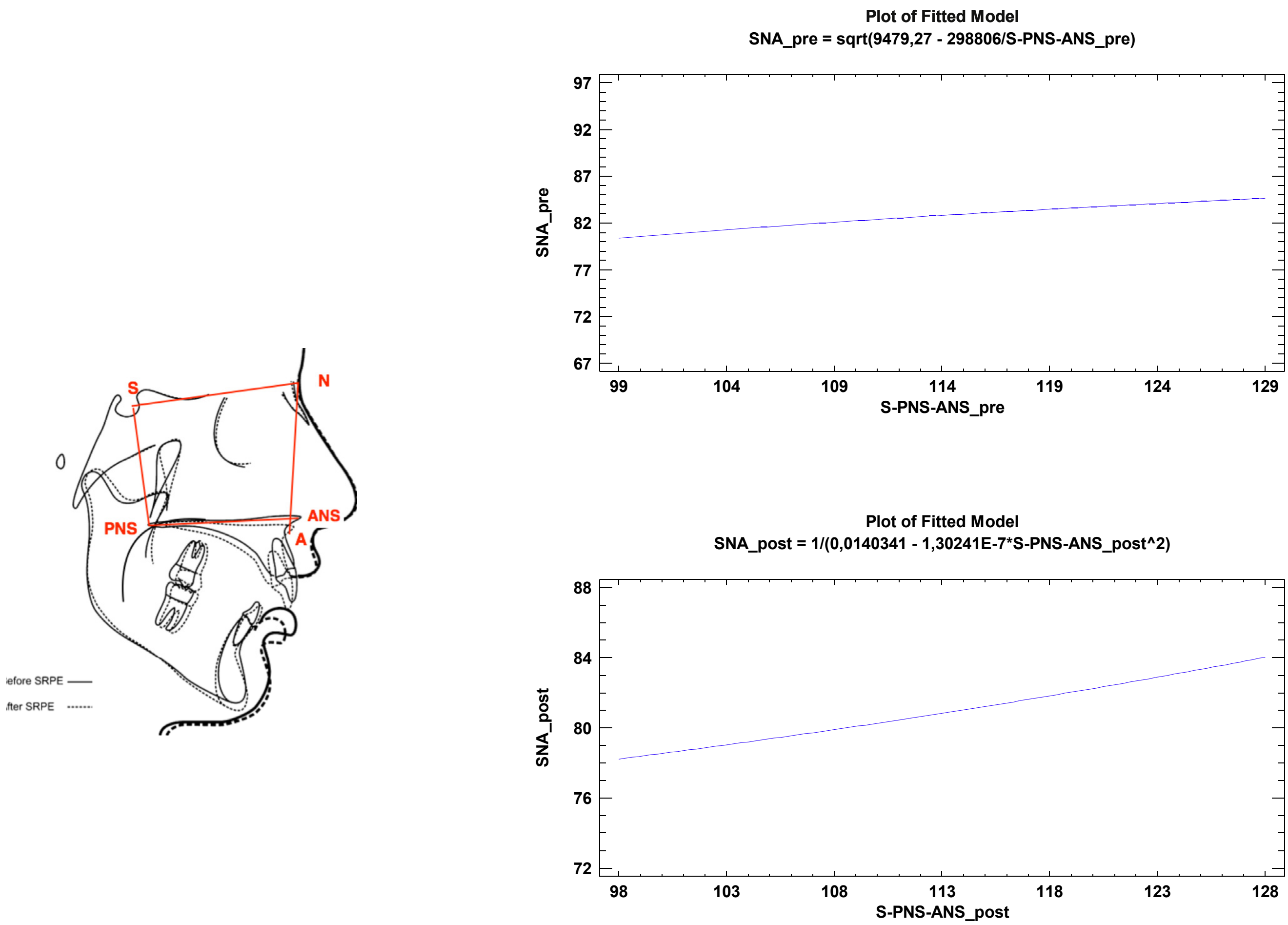


**Fig. 17.** Simple Regression – SNA vs. S-PNS-ANS describe changes in the anterior section such as opening of the S-PNS-ANS angle, and in a correlation with the SNA angle opening it indicates maxillary dropping and protrusion. The relation of S-N-PNS to SNA [$R2 = 8.9\%$, $p < 0.01$] becomes stronger post-operationally [$R2 = 11.9\%$, $p < 0.005$].

maxillary movement S-N-A and a change of 0.6° ($P < .05$) between the Frankfurt plane – N- A and a change of 0.65° ($P < .05$), and a change in the distance between the A point and N by 0.55 mm ($P < .05$). In their conclusions the authors state there are no significant changes in the vertical and horizontal movement of the maxilla and there is mild inclination of the incisors ($P < 05$) (Chung and Font, 2004).

Lagravere et al. used SARME and tooth- and bone-anchored appliances to measure vertical and horizontal changes, which were not statistically nor clinically significant (Lagravère et al., 2010).

Reports and conclusions of authors who reported lack of statistically significant changes partially agree with studies presented in this group. After a statistical analysis of data from mean changes in the angles and distances that should demonstrate the maxillary movement to the bottom and to the front are not statistically significant – Table 1.

However, changes and relations between angles and distances in some cases (Fig. 15) are statistically significant. Simple Regression - S-PNS vs. N-ANS B presents changes in the length of the anterior and posterior sections that are straight and proportional to each other. It indicates that changes in the anterior and posterior sections are related to each other and these two sections are shifted together.

The analysis of data presents statistically significant changes in the maxillary position with regard to different values of angles and distances considered together. A relationship between S-N-PNS and SNA was tested - Simple Regression - S-N-PNS vs. SNA and the following correlations are present: The relation of S-N-PNS to SNA [$R2 = 8.9\%$, $p < 0.01$] becomes stronger post-operationally [$R2 = 11.9\%$, $p < 0.005$]. It means that along with an increase in the S-N-PNS angle describing maxillary dropping in the posterior section the posterior angle S-N-A increases, namely we observe anterior maxillary movement with posterior dropping (Fig. 9). This observation complies with the authors who reported maxillary movement toward the front and bottom (Gilon et al., 2000; Günbay and Akay, 2008), The Simple Regression - SNA vs. SN-OCCL demonstrates a change in the anterior height with regard to a change in the occlusal angle. This analysis presents maxillary opening and dropping in the anterior section, and postoperatively there is statistical significance $p < 0.0001$ (Fig. 16)

Simple Regression - SNA vs. S-PNS-ANS describes changes in the anterior section. Opening of the SNA angle correlated with the opening of the S-PNS-ANS angle demonstrates maxillary dropping and protrusion. The relation of S-N-PNS to SNA [$R2 = 8.9\%$, $p < 0.01$] becomes stronger post-operationally [$R2 = 11.9\%$, $p < 0.005$] (Fig. 17).

Other relations that demonstrate statistically significant changes include changes in the occlusal plane SN-OCCL and S-PNS, a posterior section of the maxilla. According to the analysis, Simple Regression - SN-OCCL vs. S-PNS P-Value - 0.0015, post P-Value 0.0031. Changes of the occlusal angle correlate with changes in the posterior facial section.

In the post-operative analysis the change is statistically significant with regard to the incline of the angle of the occlusal plane and posterior section. It can be concluded that there is maxillary dropping in the posterior section and changes of the occlusal angle; however, average results do not indicate statistical significance S-PNS- $p < 0.5$, SN-OCL-p<01 (Fig. 13). Cited authors (Gilon et al., 2000), also report maxillary movement that is counter-clockwise. The presence of transverse changes during treatment (Figs. 4 and 5) confirm the efficacy of the method.

The following values were measured (in mm) in gypsum models (Fig. 3):

- the intercanine dimension, between the cusp tips of the maxillary canines T1-T2_3-3 was 7.68 ± 3.78 mm
- the anterior arch width, between the palatal cusp tips of the first maxillary premolars T1-T2_4-4 was 8.26 ± 3.08 mm
- the posterior arch width, between the palatal cusp tips of the first maxillary premolars T1-T2_6-6 was 5.98 ± 2.60 mm

The authors report similar ranges of expansion.

The largest expansion in the premolar area is consistent with the results of other authors. They also achieved similar ranges. The dental cast measurements showed significant increases for inter-central incisor width (5 mm), inter-lateral incisor width (5.99 mm), inter-canine width (6.10 mm), inter-first premolar width (7.07 mm), inter-second premolar width (7.10 mm), inter-first molar width (6.10 mm), and inter-second molar width (5.60 mm). The model analysis showed that the greatest range of transverse increase was in the pre region at the end of the consolidation period (Günbay and Akay, 2008).

The analysis of the effects of a change of dimensions between individual teeth on the SNA and OCCL angles did not reveal a mutual relationship. However, the CT_palet_H analysis ($P = 0.063$) is significant as it indicates a reduced level of the hard palate at the level of the first molars (Fig. 6). Similar results were obtained by R. Seeberger et al., (2011), who reported lowering of the palate by 1.2 mm. These results confirm our observations.

## 5. Conclusions

There is dropping in the anterior and posterior section and protrusion of the maxilla during surgically assisted maxillary expansion with bone-anchored appliances.

Maxillary anterior movement may depend on a surgical procedure; therefore, a procedure should be scheduled by a specific and closely cooperating team of a surgeon and an orthodontist, as in this way it is possible to predict therapeutic outcomes.

After SARME, it may be necessary to use subsequent orthognathic treatment to correct a maxillary position and to compensate dimensional relations of skeletal bases, which should be taken into account when orthodontic treatment is planned.

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## Conflicts of interest

The authors do not have any conflict of interest.

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