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Changes in transverse tooth and bone dimensions during transversal maxillary hypoplasia treatment by maxillary distraction osteogenesis using a device installed on a bone

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ABSTRACT

Introduction: A transverse maxillary hypoplasia is a deformation often observed in orthodontic patients. Various techniques are used to treat this problem.
Aim: The aim is to present results of transversal maxillary hypoplasia treatment with a bone-borne device.
Material and methods: A retrospective analysis included 27 patients, age 17–26 years (17 ± 2.6). Dental casts and X-ray were made before operation period (T1), and post distraction (T2). On the casts were determined points: on cusps of maxillary canines (3-3), first maxillary premolars (4-4) and first maxillary molars (6-6). Angles and distances were measured on standard posterior-anterior (PA) images.
Results and discussion: At the 3-3 level, the average expansion was 5.8 mm, at the 4-4 level the average expansion was 7.3 mm, at the level of 6-6 palatial cusps the average expansion was 6.11 mm. Measurements in the PA X-ray were performed at the nasal cavity, with the average dimensions being 29.03 mm before treatment, and 31.95 mm post-treatment. The angle was measured between first molars (6-6_ang) and the anterior nasal spine before and after treatment, with a significant change in that angle from 98.93° on average to 102.89° after distraction.
Conclusions: Use of maxillary distraction osteogenesis with bone-borne device in maxillary expansion is an effective treatment method. Maxillary expansion results in increase of the nasal cavity. Used distractor is easy to operate for the patient.

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1. Introduction

A transverse maxillary hypoplasia is a deformation often observed in orthodontic patients.[1,2] For the first time, the maxillary correction was introduced as a treatment method by Angel in 1860. Through the years, various techniques for treatment of transversal maxillary hypoplasia were developed. For example, Hass used acrylic plates supported on soft tissues and teeth, to ensure perpendicular expansion.[3] With time, other orthopedic procedures using Hyrax screws have been widely applied. Treatment of transverse maxillary deformities prepares the dental arch for orthodontic treatment, improves the appearance (buccal corridors), the occlusal and mastication function, as well as enlarges the nasal cavity. Various techniques are used for treatment of transverse maxillary hypoplasia, starting with slow orthodontic expansion (SOE),[4] through rapid palatal expansion (RPE) using devices anchored on teeth and recommended in treatment of narrowings about 5 mm and young patients.[5–10] Another technique is surgically assisted rapid maxillary expansion (SARME). This group covers procedures with expanding devices, installed on teeth or bones. Also, the scope of surgical intervention can vary, from partial osteotomy to complete cutting of bone connections around the osteotomy site.[11,12] Another group includes multisegmental maxillary osteotomy, a corrective treatment of facio-occlusal deformities during one procedure.[13,14] Each method bears a risk of specific complications. With SOE and RPE, there is a risk of damage to peridontium, abutment teeth, bones, as well as of deformation recurrence.[15–19] To avoid complications resulting from specific orthopedic treatment limited to young patients and narrowings not more than 5 mm, SARME is used. In 1999, Mommaerts described a method using a device anchored on maxillary bones (transpalatal distractor – TPD).[20] The advantage of this method is gradual expansion of the cut bone and soft tissues, including hard palate tissue, mastication muscles and fascia. This should guarantee stable treatment results during final correction of deformation. Also the effect of SARME-TPD on a transverse dimension of the nasal cavity by expanding its bottom is of importance.

2. Aim

The aim of this paper is to present results of transversal maxillary hypoplasia treatment with a device installed on bones using transpalatal distraction osteogenesis.

3. Material and methods

A retrospective analysis in a group consisting of 27 patients (9 female and 18 male) was conducted. Patients' age was

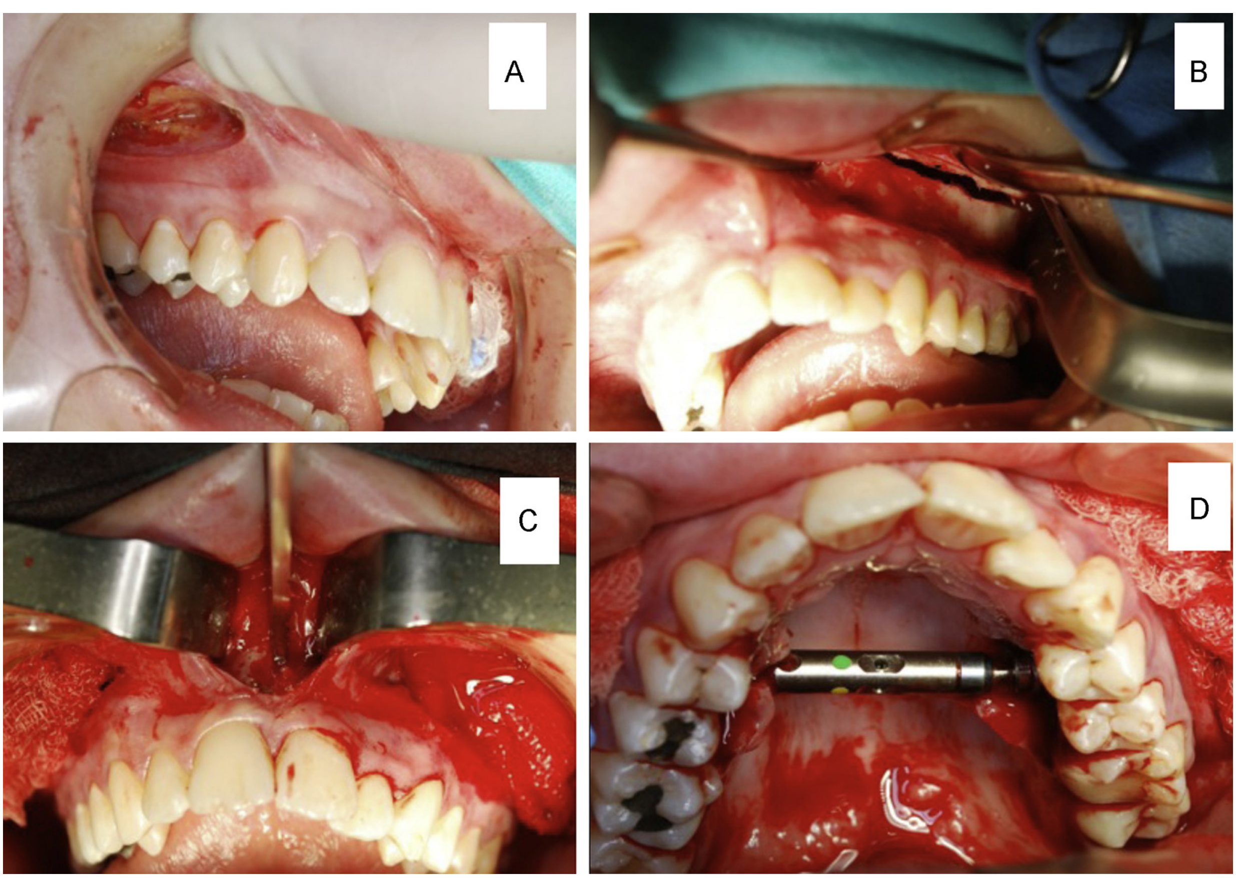

Fig. 1 – Intraoperative view. (A) Soft tissue incision; (B) lateral wall osteotomy line; (C) midline osteotomy; (D) distractor device in situ.

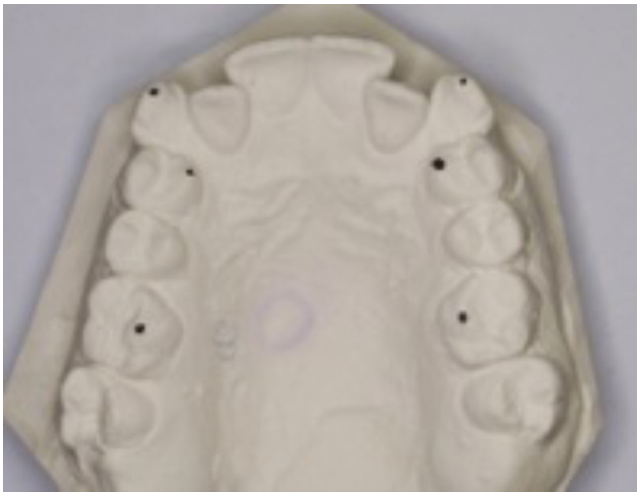

Fig. 2 – Model measurements.

ranging from 17 to 26 years, an average age of 17 ± 2.6. Patients qualified for treatment had maxillary hypoplasia with a transverse deficit of more than 5 mm. The statistical analysis was performed in Statgraphics Centurion XVI, and included the summary statistics and analysis of linear regression, ANOVA, and *t*-test because normal distribution was detected for all variables. The *t*-tests for paired samples were performed for pre- vs. post-treatment measures, and *t*-test for independent samples for comparisons other than pre- vs. post-treatment. If the P for this test was less than 0.05, the null hypothesis was rejected at the 95.0% confidence level and confirmed the significance of differences between pre- vs. post-treatment results. The approval of the Bioethics Committee No 26/2013/V was obtained. The surgery included Le Fort I maxillary osteotomy involving the posterior maxillary surface, the zygomaticoalveolarcrest, an anterior wall of the maxillary sinus and an edge of the piriform aperture, followed by osteotomy in the medial line between roots of central incisors. A connection with the pterygoid process was separated behind the maxillary tuberosity. The nasal septum was not separated from the bottom of the cavity. On a palatal maxillary surface, a T-shaped incision was made in mucosa and periosteum between the first molar and the second premolar, exposing the bone. Then, after cutting the mucosa between the first upper molar and the second upper premolar, a palatal distractor, Titamed Smile Distractor, was installed, consisting of two screws and a cylinder, supported on palatine processes of the maxilla with plates attached with self-drilling screws (Fig. 1). The distractor is unscrewed like a bottle screw. The device was activated 7 days after the procedure. The distraction followed the protocol with first the activation period – two turns in the morning and in the evening, with one turn corresponding to 0.25 mm. Dental casts were made one week before surgery (T1 period) and 3 months after the distractor was blocked (T2 period). Radiological scans were performed in the T1 and T2 periods. On the casts, points on cusp points of maxillary canines (3-3), first maxillary premolars (4-4) and first maxillary molars (6-6) were determined (Fig. 2). Then the linear measurements were performed in the periods T1 and T2, and differences for T1-T2 3-3, T1-T2 4-4, T1-T2 6-6 were calculated. Angles and distances were measured on standard posterior-anterior (PA) images, after marking of the individual skeletal radiological points: PA_nosebase_PRE/POST – length of bone nasal base in a PA radiogram before treatment; 6-6_buctub_PRE/POST – distance between first premolars before treatment; Crest_PRE/POST – distance between zygomaticoalveolarcrests in a PA radiogram before and after treatment; 6-6_ang_PRE/POST – angle between anterior nasal process and first premolars in a PA radiogram before and after treatment (Fig. 3).

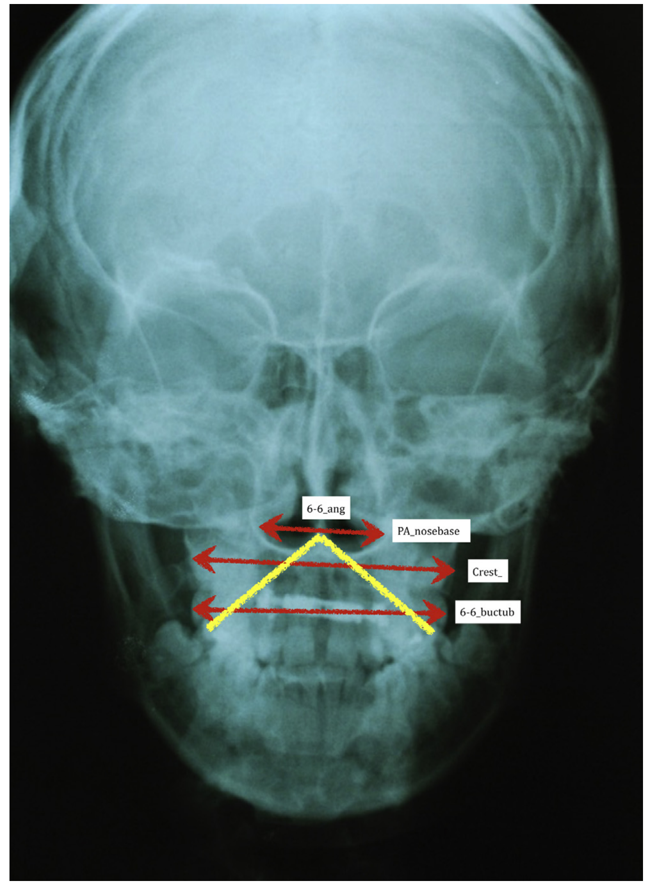

Fig. 3 – X-ray measurements.

4. Results

Measurements were performed in dental casts in the periods T1 and T2. At the cusp level of 3-3, 4-4, and 6-6 teeth, the statistical test showed a statistically significant change ($P > 0.7$). At the 3-3 level the average expansion was 5.8 mm, at the 4-4 level the average expansion was 7.3 mm, and at the level of 6-6 palatial cusps the average expansion was 6.11 mm (Fig. 4).

Measurements in the PA X-ray craniofacial scan were performed at the nasal cavity – lateral nasal walls, PA nosebase_PREi POST, with the average dimensions being 29.03 mm before treatment, and 31.95 mm post-treatment, PA_nosebase. The statistical analysis showed that $t = -4.4339$, $P < 0.0005$ (Fig. 5).

	T1-T2 3-3	T1-T2 4-4	T1-T2 6-6
Count	27	27	27
Average	5.81481	7.37037	6.11111
Median	6.0	7.0	6.0
Standard deviation	3.30544	3.24805	2.8465
Minimum	0	2.0	0
Maximum	12.0	15.0	14.0
Range	12.0	13.0	14.0
Stnd. skewness	-0.139097	1.84596	0.889192
Stnd. kurtosis	-0.420983	0.796906	1.54162

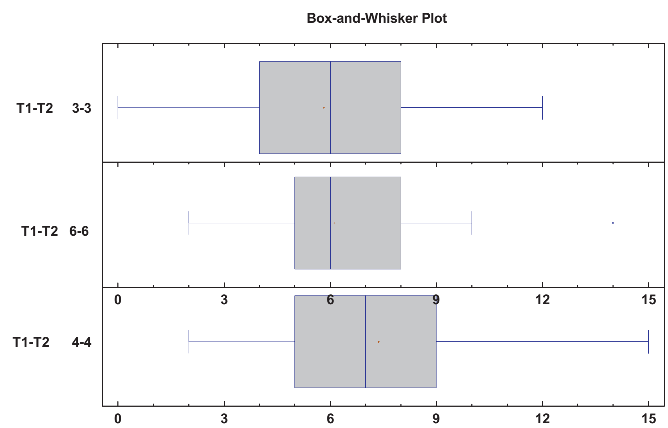

Fig. 4 – Measurements performed in dental casts in the periods T1 and T2. At the cusp level of 3-3, 4-4, and 6-6 teeth.

	PA_nosebase_PRE	PA _nosebase_POST
Count	27	27
Average	29.0315	31.9526
Median	29.26	31.86
Standard deviation	3.89835	4.10409
Minimum	22.06	22.77
Maximum	36.23	40.7
Range	14.17	17.93
Stnd. skewness	-0.0156797	-0.176396
Stnd. kurtosis	-1.08935	-0.0722006

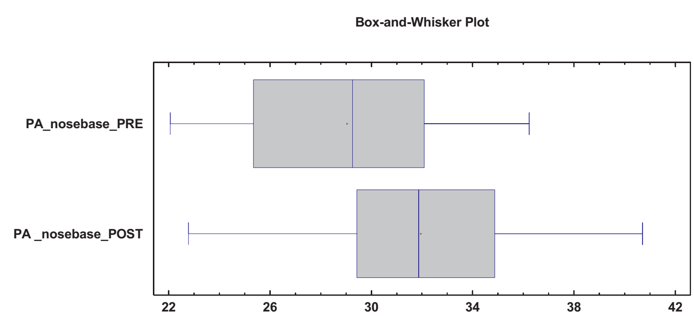

Fig. 5 – Measurements in the PA X-ray craniofacial scan performed at the nasal cavity – lateral nasal walls, PA nosebase_PREi POST, with the average dimensions being 29.03 mm before treatment, and 31.95 mm post-treatment, PA_nosebase.

Measurements were performed at the cusp level (cylinders on rings – 6-6_buctub) of the first maxillary molars: 6-6 buctub, recording an average change from 57.13 mm to 63.07 mm, 6-6_buctub. The statistical analysis showed that $t = -5.1010$, $P < 0.00005$ (Fig. 6).

Measurements were made at the level between points on the zygomaticoalveolar crest, where the average measurement was 60.43 mm before treatment and 64.923 mm post-treatment. The statistical analysis showed that $t = -4.1668$, $P < 0.0005$ (Fig. 7).

A relationship was analyzed between the 6-6 buctub and PA nosebase measurements before and after treatment. A visible linear relationship was established between the 6-6 distance and the nasal cavity base, PA nosebase, before and after treatment. Analysis of linear regression revealed that a significant relationship between PA_nosebase and 6-6_buctub existing in pre-treatment population at the 95.0% confidence level ($P < 0.01$) disappeared after treatment ($P = 0.0773$) (Fig. 8).

Measurements were also performed between points on the zygomaticoalveolar crest, and compared with the nasal base dimension, PA nosebase, before and after treatment. A linear relationship was also disclosed for the increase in pre- and post-treatment dimensions (Fig. 9).

The angle was measured between first molars, 6-6_ang, and the anterior nasal process before and after treatment, with a significant change in that angle from 98.93° on average to 102.89° after distraction (Fig. 10).

The maxillary expansion was correlated with patients' gender. The larger expansions were achieved at the cusp level of maxillary canines, 3-3, first maxillary premolars 4-4 and first maxillary molars 6-6 in the group of male patients. The maxillary expansion range was the largest in the female group. A disorder type was correlated with the narrowing range in the studied group, for relevant measurement scopes of 3-3, 4-4, 6-6. Gender dependent results were correlated with transverse palatal distraction in canine regions of maxilla ($P = 0.0509$) (Fig. 11).

The largest average expansion at the 3-3 level was achieved in the class III disorder group (Fig. 12). The largest maximum expansion range was achieved in the maxillary hypoplasia group. At the 4-4 level, expansions in the class II, class III and maxillary hypoplasia groups were similar. At the 6-6 level, the

	6-6_buctub_PRE	*6-6_buctub_POST*
Count	27	27
Average	57.1356	63.0748
Median	58.1	63.1
Standard deviation	4.57902	6.36444
Minimum	47.68	50.63
Maximum	65.35	77.17
Range	17.67	26.54
Stnd. skewness	-0.917074	0.194019
Stnd. kurtosis	-0.44295	-0.254666

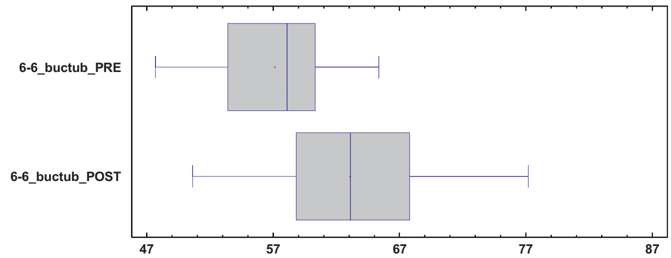

Fig. 6 – Measurements performed at the cusp level (cylinders on rings – 6-6_buctub) of the first maxillary molars: 6-6 buctub, recording an average change from 57.13 mm to 63.07 mm, 6-6_buctub.

	Crest_PRE	*Crest_POST*
Count	27	27
Average	60.4304	64.9233
Median	59.64	64.01
Standard deviation	5.42671	6.65299
Minimum	49.53	54.62
Maximum	72.35	80.37
Range	22.82	25.75
Stnd. skewness	0.855111	0.861654
Stnd. kurtosis	0.248624	-0.383467

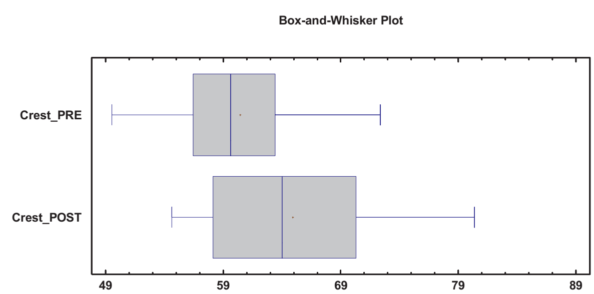

Fig. 7 – Measurements made at the level between points on the zygomaticoalveolar crest, where the average measurement was 60.43 mm before treatment and 64.923 mm post treatment.

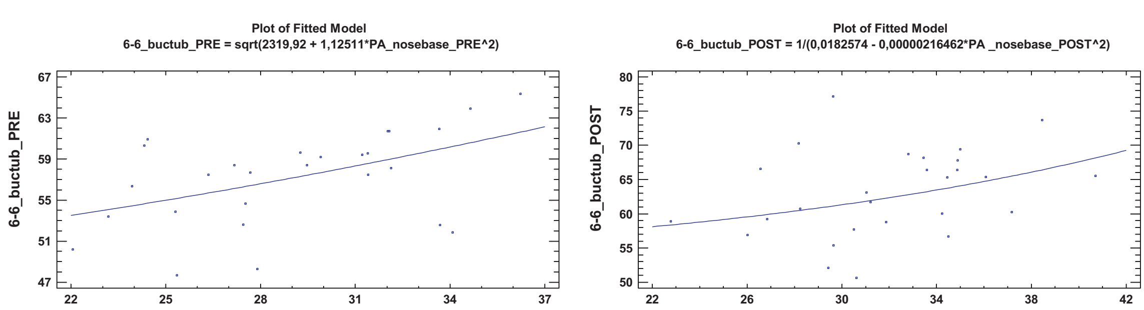

Fig. 8 – A relationship between the 6-6 buctub and PA nosebase measurements before and after treatment.

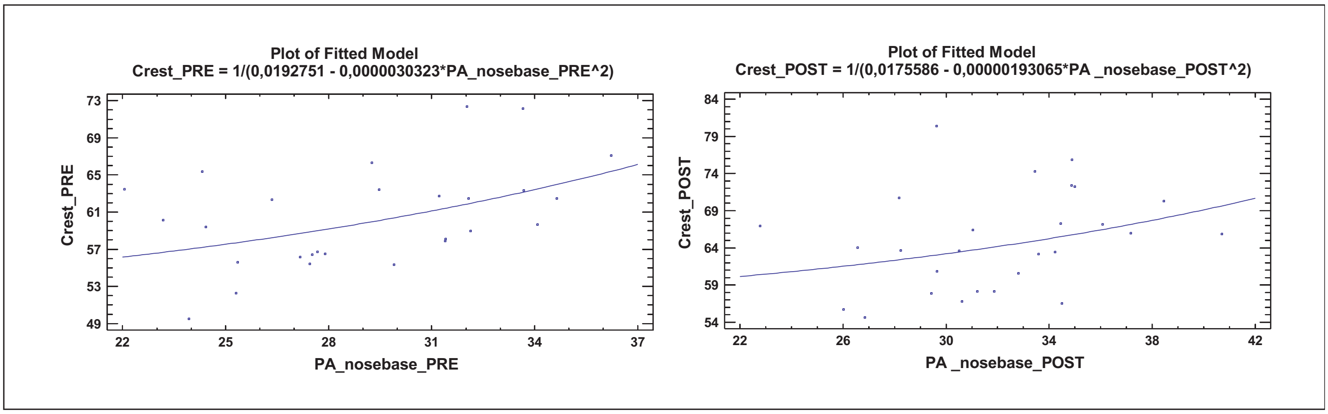

Fig. 9 – Measurements performed between points on the zygomaticoalveolar crest, and compared with the nasal base dimension, PA nosebase, before and after treatment.

	6-6_ang_PRE	6-6_ang_POST
Count	27	27
Average	98.9333	102896
Median	97.0	101.8
Standard deviation	11.3193	10.3343
Minimum	82.4	89.2
Maximum	120.8	128.9
Range	38.4	39.7
Stnd. skewness	0.618065	1.48704
Stnd. kurtosis	-1.31545	0.0999347

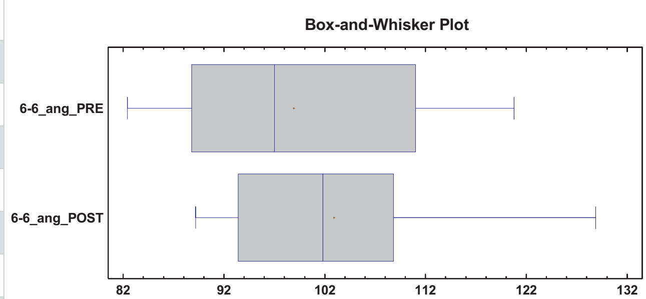

Fig. 10 – The angle measured between first molars, 6-6_ang, and 149 the anterior nasal process before and after treatment, with a 150 significant change in that angle from 98.938° on average to 151 102.898° after distraction.

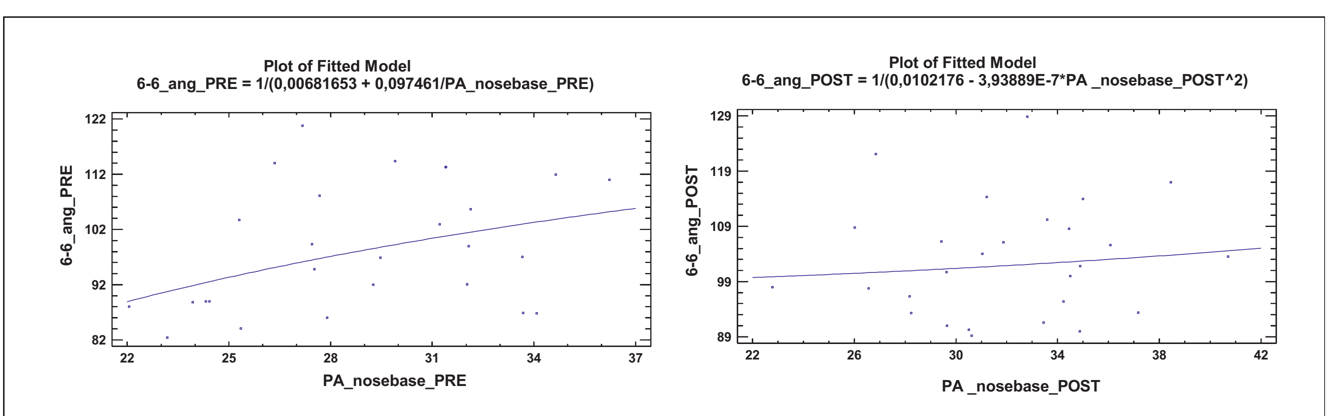

Fig. 11 – The maxillary expansion correlated with patients' gender.

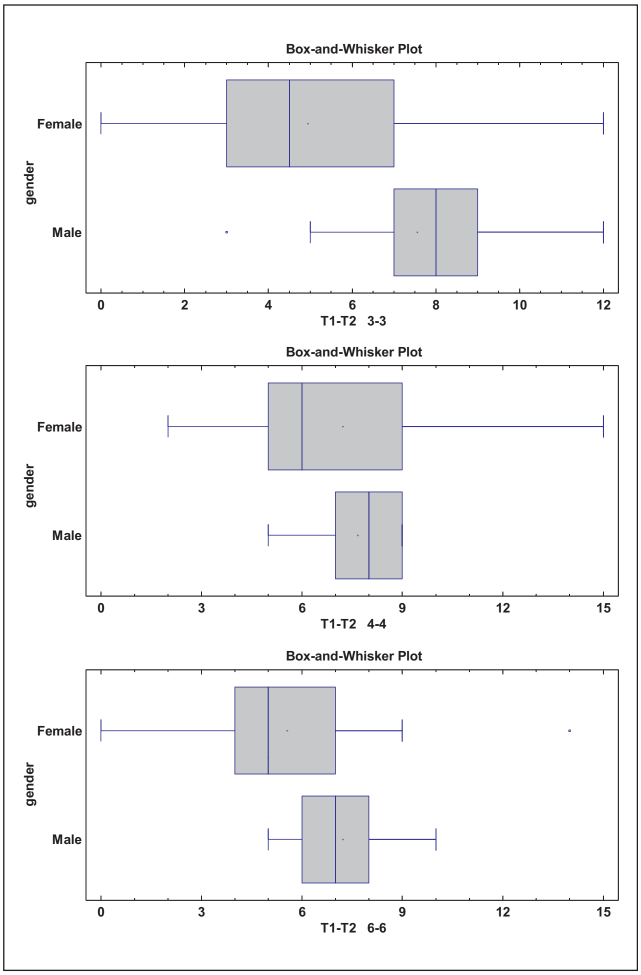

Fig. 12 – Expansion at the 3-3 level achieved in the class III disorder group.

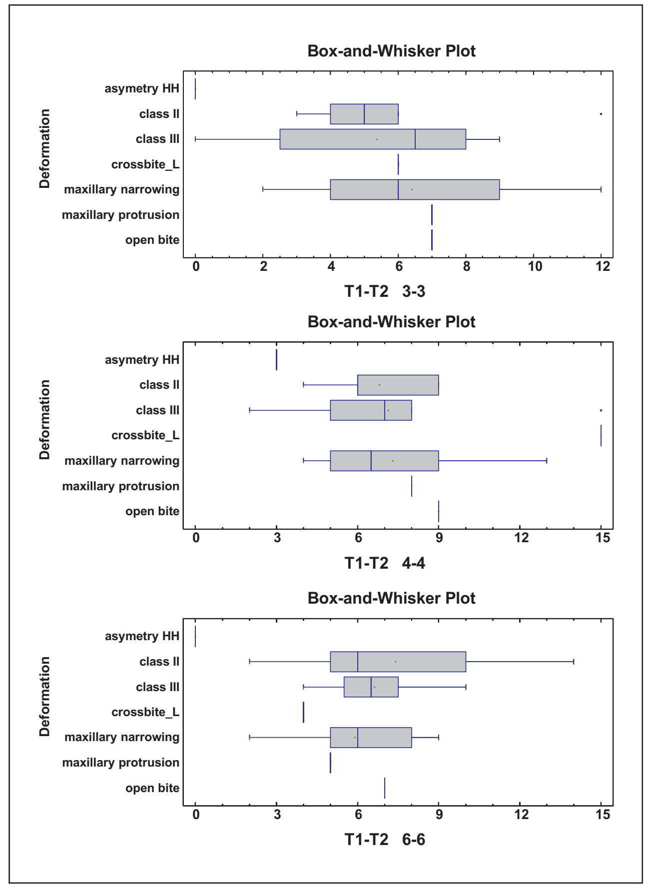

Fig. 13 – At the 4-4 level, expansions in the class II, class III and maxillary hypoplasia groups were similar.

largest range and the largest maximum expansion was achieved in the class II group (Fig. 13).

5. Discussion

The aim of the study was to evaluate skeletal and dental transverse changes following distraction osteogenesis using a bone-supported device.[5] The SARPE is a very well described method for correction of transversal hypoplasia.[16,21,22] Bone-anchored transverse palatal distraction osteogenesis is one of the treatment options. It was proposed by Mommaerts to avoid complications that can occur during treatment with other methods.[20] These complications may affect teeth, bones and soft tissues, and include: tooth extrusion, lateral tooth luxations, bending of the vestibular lamella of the maxillary alveolar process, gingival recessions, bone atrophy, palatine soft tissue necrosis, undesired opening of the palatine suture, periodontal compression and root resorption, unstable treatment results with recurrence and required overcorrection, and non-specific pains.[23–27] The patient's age is a main indication for surgically assisted maxillary expansion. The literature does not present a uniform opinion about a minimum age at which the treatment can be started. The surgical treatment depends on maturity of the bone skeleton. As the other studies show, maturing and ossification of the palatal suture occurs at various age. Mommaerts reports 14 years as the age when areas of bony resistance can be released.[20] In the series of studied cases, the average age was 17 ± 2.6, the youngest patient was 17 years, and the oldest was 26 years old. The analysis of a relationship between the age and transverse dimensions shows a linear relationship for condition before and after treatment. With the age, the individual transverse maxillary dimensions increase. Currently, there is no consensus on maxillary transversal hypoplasia treatment, in terms of a method and device anchoring, as well as patients' age. The treatment method depends on experience of a treatment team and personal preferences of an orthodontist or surgeon. In reported cases, a distractor attached to maxillary bones in accordance with the protocol proposed by Mommaertes was used. The age and narrowing range were main indications for use of a device of that type. As it can be seen in the results, effective expansion was achieved in every case.[28–31] Measurements performed on casts confirm achieved increase in transverse dimensions, at the levels: 3-3 – average distance of 5.8 mm, 4-4 – average distance of 7.3 mm, and 6-6 – 6.1 mm, and this is confirmed by other researchers. The largest expansion in the premolar area is consistent with 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 premolar region at the end of the consolidation period (Tayfun Günbay et al.).[16,27,32] This can be explained by larger forces preventing expansion in the posterior maxillary region, and by the fact that the force was applied near the middle of the maxillary alveolar process. That observation is confirmed by imaging tests of finite elements.[31,33,34] When PA X-ray scans were analyzed, the nasal base expansion was seen, and it should result in improved patency of the nasal cavity. Due to its specific structure, any increase in the nasal cavity dimensions improves its patency.[35] Changes in a transverse dimension between 6-6 teeth and reduction in the angle 6-6_ang are interesting. These data indicate effective expansion of bone fragments, and changes in the angles are correlated with the nasal base expansion and the 6-6 dimension. The change in the 6-6_ang angle, before and after treatment, indicates a lowering of the nasal spine and, at the same time, of the hard palate. Another important factor is the maxillary structure and thickness of reinforcement regions in the facial skeleton. Regions of bony resistance to lateral forces in the middle facial skeleton include the piriform aperture (frontal reinforcements), the zygomaticoalveolarcrests (lateral supports), and the pterygopalatine fossa (posterior reinforcements). The Le Fort I maxillary osteotomy was performed with all bone connections around the maxilla and medial osteotomy without separation of the nasal septum proposed by Momeartes guarantees correct, problem-free expansion of bone fragments. Reinbacher et al. also confirm advantageous results of this technique, and in their conclusions they do not see a difference in the distraction range in cases with the nasal septum separated[5,12,31,36–38] and do not confirm correctness of this technique and the opinion of other authors recommending full osteotomy during maxillary expansion.[31,39]

There are also differences in approach to the connection between the pterygopalatine fossa and the maxilla. Studies comparing treatment results for broken and intact pterygopalatine connection report similar treatment results for both cases.[40] Other authors present studies in adult patients and results of maxillary expansion not assisted surgically. The author presents 47 cases treated successfully. In his conclusions, the author discusses a problem of refusing the surgical treatment by adult patients; in such cases this technique can be proposed as an alternative.[41–44] Other proposed techniques for maxillary transversal hypoplasia correction include a one-stage expansion during orthognathic surgery. Many authors emphasize the stable treatment results, however, a burden of jaw segmentation during one surgery is also of importance, and the stable treatment results are questioned.[13,45]

Possibilities for one-stage expansion are also limited, and the reported data also are in contradiction to the effect of external muscle forces and of palatine soft tissue tensions on the stable treatment result.[46] When a decision is made about the intervention scope, another discussed element is application of a device for maxillary expansion. So far, there is no consensus on the advantage of tooth- or bone-anchored devices.[22] When the data are analyzed and compared with other authors using SARME either with tooth or with bone anchoring, the expansion results are similar. However, in the interview the patients report significantly easier operation of the distractor, in comparison to the Hyrax screw.[16,32,47] Tooth-anchored devices have a negative effect on abutment teeth and cause dental and process complications. In the presented data, no complications occurred in teeth or supporting structures.[23–27]

The period of maxillary distraction or expansion is followed by consolidation, and the devices stop being active and turn into passive, remaining in the oral cavity for 3–6 months. Bone-anchored devices do not affect teeth and their design, in comparison to, e.g., Hyrax, is simple and allows maintaining correct oral hygiene. In our case, a bone-anchored transpalatal distractor was used. Use of a device of this type seems to be correct, as it transfers forces directly onto the maxillary bones and works in parallel. Also, as it is anchored on the bone, it is close to the bony resistance region and ensures precise distribution of expansion forces.[35]

6. Conclusions

1. Use of maxillary distraction osteogenesis in maxillary expansion is an effective treatment method.
2. Maxillary expansion results in increase of the nasal cavity bottom.
3. Used distractor is easy to operate and helps to maintain correct oral hygiene.

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