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An Analysis of Early Changes to the Craniofacial Skeleton Induced by Transpalatal Distraction in a Patient with Maxillary Constriction, Based on Computed Tomography Scans – Case Report

Analiza wczesnych zmian w szkieletcie czaszki twarzowej po leczeniu zwężenia szczęk metodą dystrakcji przepodniebiennej na podstawie tomografii komputerowej – opis przypadku

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A – koncepcja i projekt badania, B – gromadzenie i/lub zestawianie danych, C – analiza i interpretacja danych, D – napisanie artykułu, E – krytyczne zrecenzowanie artykułu, F – zatwierdzenie ostatecznej wersji artykułu

Abstract

Transpalatal distraction is a recognized surgical treatment of transverse maxillary deficiency in adult patients. In skeletally mature individuals, rapid maxillary expansion (RME) is ineffective or leads to dental and periodontal complications. Transpalatal distraction works on the principle of distraction osteogenesis, increasing the maxillary base width and its transverse dimensions. Skeletal expansion of the maxilla will lead to an increase in the volume of the nasal cavity with proper conversion of the nasal breathing track. The increase in width of the maxilla will also overcome the unsightly dark corridors during a smile. The clinical manifestation of the maxillary expansion during active distraction treatment is the emergence of diastema between the maxillary central incisors. Currently available diagnostic imaging techniques such as computed tomography (CT) and 3D image reconstruction of craniofacial bone structure enable precise analysis of active treatment.

The paper presents the case of a 29-year-old woman with maxillary constriction and skeletal class III malocclusion, treated with transpalatal distraction. The changes in maxillofacial complex were quantified based on the selected axial computed tomography scans taken before and after the end of active treatment. Furthermore, a 3D reconstruction of the craniofacial skeleton was performed so as to obtain a realistic picture of TPD-induced changes (Dent. Med. Probl. 2016, 53, 1, 134–141).

Key words: computed tomography, maxillary constriction, transpalatal distraction, crossbite.

Słowa kluczowe: tomografia komputerowa, zwężenie szczęki, dystrakcja przepodniebiennej, zgryz krzyżowy.

Transverse maxillary deficiency in adults still poses a challenge in orthodontics. Maxillary constriction is clinically manifested as a narrow palate and a high palatal vault, a complete unilateral or bilateral crossbite and dark buccal corridors. The dysfunction secondary to malocclusion may also be associated with impaired nasal patency leading to open-mouth breathing and all its sequelae [1]. It is difficult to estimate the prevalence of transverse maxillary deficiency in the adult population. According to Bailey [2], approximately 30% of all

adult patients requiring orthodontic surgery present with maxillary constriction. Midpalatal suture expansion, associated with expanding the maxillary bone base, increasing arch widths and restoring proper interarch relationships is a well-established treatment of severe maxillary constriction. The first reports on midpalatal suture expansion date back to the 19th century, when Talma and Lefoulon used a palatal expander with a C-shaped spring as the main source of applied force. Then, in 1860, Angella reported in Dental Cosmos a case

of a 14-year-old patient with transverse maxillary deficiency. He used an appliance with a screw located centrally on the hard palate. Haas, who developed his own appliance in 1961 and widely popularized his own treatment approach worldwide, is considered to be the father of contemporary therapies of transverse maxillary deficiency [3].

The transverse maxillary dimension may be increased using orthodontic methods (SOE – slow orthodontic expansion, RPE – rapid palatal expansion), surgically assisted orthodontic methods (SARPE – surgically assisted rapid palatal expansion, SARME – surgically assisted rapid maxillary expansion) and surgical methods (TPD – transpalatal distraction, LFI – E – segmented Le Fort I osteotomy with expansion) [4].

The treatment method should be chosen based on patient age and their skeletal maturity. The midpalatal suture in patients with primary dentition and early mixed dentition is composed of connective tissue and the midface skeleton does not show resistance to orthodontic expanders. In older patients, with late mixed dentition, the expansion is typically possible with the use of a Hyrax appliance as the midpalatal suture closes due to mineralization.

In skeletally mature individuals, rapid maxillary expansion (RME) is ineffective or leads to dental and periodontal complications [5–8]. In order to avoid treatment failure in adult patients, surgically assisted methods were introduced [9, 10].

The main goal of surgically assisted maxillary expansion is to reduce or eliminate the bone resistance of the maxilla. The surgery includes an incision created within the maxilla from the piriform aperture, through its anterior surface and zygomaticoalveolar crest to its insertion into the sphenoid bone, which is along the LeFort I osteotomy line. As an essential part of the procedure, the midpalatal suture is surgically separated [3]. The force-generating appliance is either a tooth-anchored expander (SARME, surgically assisted rapid palatal expansion) or a bone-anchored transpalatal distractor (TPD, transpalatal distraction) [4, 9]. The transpalatal distractor applies force directly onto the palatine bone, which helps avoid the adverse effects of expander force applied onto teeth in the palatal expansion (SARME) method.

Midpalatal suture expansion alters the structure and physiology of the facial skeleton. The lowering of the palatal vault increases the volume of the nasal cavity, which improves facial features and the patency of the upper respiratory tract [11, 12].

In young individuals, the center of rotation of maxillary bones, as they expand, is thought to be located within the frontonasal suture. However, with age it lowers towards the midpalatal suture

and shifts caudally [13, 14]. The most noticeable clinical manifestation of midpalatal suture expansion is a diastema between the upper medial incisors.

Case Report

A 29-year-old female was referred to the Department of Maxillofacial Surgery in Wrocław by her orthodontist, for surgical treatment of a complex gnathic defect. She was diagnosed with skeletal class III malocclusion and transverse maxillary deficiency (Fig. 1 a–c). The complex orthodontic and surgical treatment plan assumed transpalatal distraction (TPD) as the first stage of treatment, followed by deficit compensation and a second procedure of bimaxillary osteotomy (BIMAX). The preoperative diagnostic imaging included plain craniofacial computed tomography. Computed tomography of the craniofacial bones makes it possible to appreciate all of the significant anatomical structures, which may show individual variability, and their relationships, as well as to plan the surgical intervention.

The surgery was performed under general anesthesia. The Le Fort I osteotomy was performed from the symmetrical approaches in the oral vestibule and maxillary labial frenum, including the bilateral separation of the maxilla from the pterygoid processes of the sphenoid and surgical mobilization of the midpalatal suture. After checking the symmetry and mobility of the palatal leaves, the Uni-Smile® transpalatal distractor (Titamed, Belgium) size 16 was fixed on the hard palate between the second premolars. The abutment plates were located horizontally at 1.0 cm from the gingival margin and perpendicularly to the skeletal line of the midpalatal suture. Intraoperative distractor activation yielded a 1.0 mm wide diastema. The wound was closed using 4-0 absorbable sutures. The medical treatment involved peri- and postoperative preventive antibiotic therapy, using analgesics, anti-edema agents and decongestant nasal drops.

A standard distractive treatment protocol was followed including the latency, distraction, and retention phases. The surgery was followed by a 6-day latency phase. The distractor did not expand spontaneously owing to the blocking screw being placed and tightened intraoperatively. During the distraction phase, the patient activated the distractor herself at home, twice daily (AM/PM) by a quarter turn, which corresponds to 0.5 mm expansion per day. The duration of the active treatment phase depends on the transverse maxillary deficiency. In this particular case, the distraction phase lasted for 15 days. The total number of acti-

Fig. 1. a–c. Bite before treatment

Fig. 2. Panoramic x-ray before treatment

variations was 29 (each being a quarter turn), which corresponds to the overall expansion of 7.25 mm.

Directly after completion of the active treatment, the follow-up, non-enhanced craniofacial CT scan and a posteroanterior (P-A) cephalometric radiograph were performed. The most noticeable treatment-induced change was a diastema as a clinical manifestation of midpalatal suture expansion (Fig. 4 a–c).

Treatment Outcome Evaluation

Treatment outcomes were quantified based on the measurements of the axial tomograms taken before (time point T1) and after the active treatment (time point T2). The axial tomograms selected for the analysis were taken at the level of

Fig. 3. Frontal cephalometry x-ray before treatment

the incisive foramen and the anterior nasal spine. The measurement reference points were chosen based on the criterion of a sharp image of certain anatomical structures on the tomograms, which enabled measurement reproducibility. The five transverse measurements (L1, L2, L3, L4, L5) were in the axial plane at the level of the incisive foramen (Fig. 7 a–b). The measurements quantified skeletal changes in the transverse maxillary

dimension, topographically related to the following tooth groups: first medial incisors, canines, first and second premolars as well as first molars. On the computed tomography scans at the level of the nasal spine, three distances were marked (W1, W2, W3), corresponding to the increase of transverse maxillary dimension at the respective teeth group levels: canines, second premolars and first molars (Table 1, Figure 8 a–b). The selected

Fig. 4. a–c. Bite after treatment

Fig. 5. Panoramic x-ray after treatment

Fig. 6. Frontal cephalometry x-ray after treatment

Table 1. The analysis of changes in transverse maxillary dimension before and after the active treatment based on computed tomography scans – see the article for the legend

	L1	L2	L3	L4	L5	W1	W2	W3
T1	10.35	32.58	42.44	44.90	52.98	27.95	43.00	51.51
T2	20.58	40.76	49.81	52.73	59.63	34.89	49.46	56.61
ΔT	+10.23	+8.18	+7.37	+7.83	+6.65	+6.94	+6.46	+5.1

computed tomography scans were analyzed using OsiriX® software (Pixemo, Switzerland). The analysis was performed twice – at baseline, before

treatment commencement (T1) and after the active treatment (T2). Additionally, the evaluation of treatment outcomes and changes within the mid-

Fig. 7. CT scan – measurements on the level of incisive foramen: a) before treatment, b) after treatment

Fig. 8. CT scan – measurements on the level of anterior nasal spine: a) before treatment, b) after treatment

face skeleton induced by the transpalatal distraction included qualitative assessment based on 3D craniofacial models. The 3D model of the facial skeleton was generated based on craniofacial computed tomography using OsiriX software and subsequently saved as a jpg file (Fig. 9 a–b).

Results and Discussion

The analysis of the craniofacial skeletal changes based on computed tomography scans is one of the assessment methods applicable to surgical treatment outcomes [15–17]. Quantification of treatment outcomes based on x-ray images may be

difficult due to the inability to achieve reproducible projection and the presence of artefacts. The accurate analysis of anatomical structures and the choice of measurement reference points on the CT scans enable precise monitoring of both quantitative and qualitative aspects of maxillary expansion.

The results of transversal analysis of axial projections generated at the level of the incisive foramen and the anterior nasal spine were shown in Table 1.

The measurements at the level of the incisive foramen revealed the largest maxillary expansion near the medial incisors (+ 10.23 mm), whereas the lowest value (+ 6.65 mm) was observed near

Fig. 9. 3D CT reconstruction: a) before treatment, b) after treatment

the first molars. The measurements at the level of the anterior nasal spine revealed the largest maxillary expansion near the canines (+ 6.94 mm). The expansion gradually decreased posteriorly, amounting to 5.1 mm near the first molars. These findings correlate with the views of other authors, who observed the largest expansion of the midpalatal suture within its anterior segment and suggest that the center of rotation is situated within the frontonasal suture, resembling an unfolding fan in the sagittal plane and a pyramid in the axial plane [11–13].

Furthermore, we determined the ratio of distractor screw expansion to the increase of maxillary transversal dimension (skeletal change increments) at the predefined measurement reference points, using the following formula:

$$Z = [\Delta T]/7.25$$

where $[\Delta T]$ stands for changes of dimensions at the following measurement points: L1, L2, L3, L4, L5, W1, W2 and W3, respectively; whereas 7.25 is a constant expressed in millimeters and stands for the distractor screw expansion.

Measurement results are shown in Table 2.

Our measurements indicate that the most significant skeletal change takes place within the an-

terior maxilla near the medial incisors (L1), where the ratio of distractor screw expansion to maxillary transverse dimension increase is approximately 1:1.5 (exactly 1.41). This ratio decreases posteriorly, reaching almost 1:1 (exactly 0.97) near the first molars (L5). On the average, at the level of the incisive foramen, each 1.00 mm expansion of the distractor screw yielded an increase of maxillary transverse dimension by 1.41 mm and 0.97 mm near the upper incisors and first molars, respectively. On the average, at the level of the anterior nasal spine, each 1.00 mm expansion of the distractor screw yielded an increase of maxillary transverse dimension by 0.95 mm and 0.70 mm near the canines (W1) and first molars (W3), respectively.

We believe this is very valuable information, which after a statistical analysis in a larger patient sample, may help develop predictable treatment plans and determine patients needs for maxillary expansion after the initial surgical intervention.

The 3D models yield the most realistic picture of changes to the craniofacial skeleton induced by transpalatal distraction.

The 3D visualization provides an interesting qualitative supplement as a three-dimensional reconstruction of the computed tomography scans.

Table 2. Analysis of changes in transverse maxillary dimension with the increasing length of the distractor

	L1	L2	L3	L4	L5	W1	W2	W3
T2–T1 $[\Delta T]$	10.23	8.18	7.37	7.83	6.65	6.94	6.46	5.1
Z	1.41	1.12	1.01	1.08	0.97	0.95	0.89	0.7

Conclusion

Computed tomography is a technique of choice in the quantification of dental and skeletal changes within the maxillofacial complex induced by transpalatal distraction in patients with transverse

maxillary deficiency. The reproducibility of projection, the absence of artefacts and deformities, as well as the high resolution and precision of imaging ensure accurate and reliable measurements. Additionally, it is possible to generate image reconstruction and 3D modeling before and after treatment.

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