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Midpalatal suture morphology and bone density evaluation after orthodontic expansion: a cone-bean computed tomography study in correlation with aesthetic parameters

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Abstract

Maxillary expansion is one of the earliest methods of obtaining space used in the field of orthodontics. Maturing craniofacial sutures along with the increase in bone density and rigidity are main causes of high resistance of the maxilla to transversal expansion forces applied to the midpalatal suture through orthodontic appliances. Fifty-three patients, with a mean age of 16.4 years and a diagnosed transverse plane orthodontic anomaly were included in this study and divided in two groups: male group and female group. Cone-beam computed tomography (CBCT) was used for measurements conducted in order to determine bone density before and after jaw expansion in different segments of the midpalatal suture: anterior, middle and posterior. In males, slightly higher bone density values were observed in the midpalatal suture than in females before and after maxillary expansion, with average values ranging from 128.5 Hounsfield units (HU) to 672.9 HU. Bone density along the maxillary suture plays an important role in the success rate of orthodontic treatment. Assessing the palatal suture maturation on CBCT images is a very promising predictor for conventional or surgically assisted jaw expansion. Intra and extraoral pictures were used to evaluate the position of the zenith in the aesthetic area and gingival aesthetic line (GAL) class. In the study, there was a significant reduction in the number of class II, class III and class IV and an implicit increase of GAL I class that ensure a pleasant transition of the gingival level between the anterior maxillary teeth. The distribution of the gingival height in terms of the classes found prior to the orthodontic treatment remained unchanged after treatment.

Keywords: orthodontic expansion, Hounsfield units, cone-beam computed tomography, smile aesthetics.

⊟ Introduction

Maxillary expansion is one of the earliest methods of obtaining space used in orthodontics. The procedure aims to increase the perimeter and transversal dimension of the upper arch, especially when there is a discrepancy in comparison to the lower jaw that could lead to malocclusions and their associated complications [1]. It has high indications in situations such as narrow maxilla in young patients [2]. This technique is not applicable in all cases given that it can develop open bite, it is prone to relapse and all improvements could be only temporarily if not retained correctly [3]. With increasing age, the natural biological behavior of maturing craniofacial sutures along with the increase in bone density and rigidity are main causes of high resistance of the maxilla to transversal expansion forces applied to the midpalatal suture through orthodontic appliances [4, 5].

Clinicians can choose from various midpalatal suture assessment techniques varying from conventional radiographs to more modern three-dimensional (3D) imaging. According to Sato *et al.*, the use of postero-anterior cephalometric radiography can provide an assessment of the transversal dimension of the face and thus facilitate the diagnosis of micrognathic maxilla as well as any orthopedic changes obtained in the rapid opening of the midpalatal suture. Being a two-dimensional (2D) image, overlaying of anatomic structures lower the accuracy of

cephalometric landmark positioning in the cephalometric analysis, which is a big part of diagnosing and assessing the maxilla and midpalatal suture in the beginning, during or at the end of any expansion intervention [6, 7]. Occlusal radiographs have been widely used in monitoring the midpalatal suture after orthodontic transversal expansion [8]. The occlusal radiograph shows that the opening of the intermaxillary suture is non-parallel; the expansion pattern is V-shaped experiencing greater values in the anterior compared with the posterior region [9].

Cone-beam computed tomography (CBCT) has made 3D assessment possible. Nowadays, it is more often applied in all fields of dentistry mainly because it is becoming more affordable and requires lower radiation for each exposure. 3D techniques have proven to have multiple advantages when compared to 2D conventional radiographs, and using them in the diagnosis and treatment plan of orthodontic patients provides a better overview of the situation [10, 11]. Impacted teeth, cleft palate, root resorption, supernumerary teeth, temporomandibular joint pathology, asymmetries, alveolar bone condition, and skeletal discrepancies requiring surgery are just a few of the current indications for the use of CBCT. It also provides detailed and valuable information about the morphology and angulation of the root of the teeth, the available alveolar bone, the jaw dimension, airway morphology, vertical malocclusions and the morphology

and pathology of the temporomandibular joint that contributes to malocclusion and could influence the decision to do maxillary expansion [9, 12].

Treatments involving dental and smile aesthetic objectives add smile analysis in the diagnosis, planning, and even treatment and prognosis stages. The evaluation of the characteristics of the smile is a necessary procedure to in orthodontic treatments in order to achieve good results and recognize the factors that could affect the observed characteristics [13].

To predict the final aesthetic result and achieve optimum results in gingival contour rehabilitation (orthodontic therapy), it is important to consider gingival contours during treatment planning. Some quantifiable clinical parameters may be helpful for the diagnosis and treatment of gingival discrepancy when gingiva is exposed [14].

Gingival zenith is directly related to the aesthetics of the smile, thus the central incisor has a zenith positioned at the distal third, the lateral incisor in the middle, and the cusp can range from anterior third through to the distal third of the tooth.

The aim of the present study is to evaluate the degree of maturation of the midpalatal suture based on suture morphology using CBCT 3D images, in order to identify whether it is possible to predict jaw expansion taking into account the bone density of the midpalatal suture as well as to observe the modification of class GAL, from an aesthetic point of view, before and after the treatment and its impact on facial aesthetics.

⊡ Patients, Materials and Methods

Patients who took part in this study were recruited from the Clinic of Orthodontics, "Victor Babeş" University of Medicine and Pharmacy, Timişoara and from a private practice in Timişoara (Romania). We collected data from each patient, intra and extraoral pictures to evaluate the position of the zenith in the aesthetic area and gingival aesthetic line (GAL) class, including CBCT images to evaluate the midpalatal suture, cephalometric radiographs, and panoramic dental radiographs. Fifty-three patients, including 27 girls and 26 boys, with a mean age of 16.4 years, each exhibiting a transverse anomaly and the need for orthodontic treatment, were evaluated.

The exclusion criteria were as follows: patients who have benefited from orthodontic therapy in the past, poor oral hygiene, chronic or autoimmune diseases, patients under medication that affect bone metabolism, omitting any diagnostic data, poor qualitative images.

To measure bone density at the palatal suture, CBCT images were taken using the Planmeca Romexis Viewer software prior to treatment and at the end of treatment when the expansion took place. With this software, more accurate measurement values can be obtained, improving the value of the diagnosis, helping the doctor formulate a precise and accurate treatment plan. CBCT imaging facilitates 3D visualization of oral and maxillo-facial structures and allows assessment of the midpalatal suture maturation.

For measuring bone density at the midpalatal suture before and after treatment, the Hounsfield unit (HU), a medical imaging parameter quantitatively indicating X-ray attenuation, was used. A CT scanner uses an X-ray beam that passes through the exposed patient and it can be detected at the exit and calculates how much of it is attenuated. The HU coefficient comprises re-calibrated values on a scale of -1024 (air attenuation coefficient) to + 3071 HU. The attenuation coefficient for pure water is 0, and that associated with the solid bone is 1000 HU. The HU scale from -1024 to +3071, is a field of representation of 4096 different degrees of gray. The maximum attenuation corresponds to pure white (3071 HU) and the minimum is associated with the presence of a bright black (1024 HU).

Images obtained with CBCT before and after treatment were introduced into the Planmeca Romexis Viewer software and a parallelepiped was created with dimensions of 3.6 mm in width, 15.45 mm in height and 3.6 mm in depth, resulting in a volume of 200 mm³. This parallelepiped was placed along the midpalatal sutures, taking into account three markers: the anterior, middle and posterior markers, thus obtaining three mean density values for each area. This software allowed us to visualize the measurements made in different incidences: coronal, sagittal, axial and 3D, both concurrently and separately.

⊡ Results

The 53 patients were divided in two groups: males and females. Measurements were conducted in order to determine bone density before and after jaw expansion in different segments of the midpalatal suture: anterior, middle and posterior. CBCT images taken before and after expansion treatment were inspected in the axial, coronal and sagittal planes and the three segments of the suture were outlined for bone density determination. Suture modifications were more evident in the axial plane (Figures 1 and 2). An enlargement of the midpalatal area and total arch perimeter was observed, it being even more evident on the 3D model reconstruction of the CBCT acquisition (Figure 3). Bone density assessment was undertaken for the two groups (males and females) for all three segments of the midpalatal suture: anterior, middle and posterior. Bone density modifications were visible in all three planes on the CBCT (Figures 4 and 5). Mean values were calculated before and after treatment. Before treatment, values were higher than after treatment values for all three segments. The women group had lower values of bone density than the men group. Before treatment in the anterior segment, we measured a bone density of 658.7 HU for women and 672.9 HU for men, and in the middle segment, the mean values were 520.09 HU for women and 546.32 HU for men. The posterior segment was the lowest bone density values with mean results of 516.67 HU for the female group and 529.78 HU for the men group (Table 1). After the expansion treatment in the anterior segment, we measured a bone density of 321.09 HU for women and 354.24 HU for men. In the middle segment, the mean values were 128.56 HU for women and 249.35 HU for men. The posterior segment had the highest bone density values with mean results of 381.9 HU for the female group and 398.07 HU for the men group (Table 2). Prior to the start of the expansion, it was observed that for both men and women, the highest density level was measured in the anterior part of the midpalatal suture, followed by the middle suture segment. The highest value was 672.9 HU and was obtained in

the men group before treatment in the anterior segment (Figure 6). After completion of the orthodontic arch perimeter enlargement, a decrease in bone density was observed along the suture in the anterior and middle region in comparison to the posterior region for both males and females. The lowest value was in the middle segment of the women group after treatment: 128.56 HU (Figure 7).

The fusion of the maxillary suture takes place earlier in the posterior region and then progresses to the anterior part as the formation of the new bone starts. For this reason, suture opening occurs in the form of a triangle with the base located in the frontal part of the maxilla, expansion occurring predominantly in the anterior and middle areas.

In order to evaluate possible changes of the GAL line after orthodontic treatment, this was recorded in all patients enrolled in the study before and after finishing of the treatment, the examination for each individual hemiarcade (Figure 8).

Thus, before starting orthodontic treatment, at hemi-arcade 1 (h1) the situation was as follows: class I – 10 patients, class II – 19 patients, class III – seven patients, class IV – two patients (Table 3). After finishing the ortho-dontic treatment: class I – 21 patients, class II – 14 patients, class III – three patients, class IV – 0 patients (Table 4).

Concerning the classification of the GAL line, class distribution was on hemiarcade 2 (h2) in patients before the onset of orthodontic treatment: class I – 12 patients; class II – 11 patients, class III – 14 patients, and class IV – one patient. After orthodontic treatment the GAL classes were: class I – 29 patients, class II – five patients, class III – three patients, class IV – one patient (Tables 5 and 6).
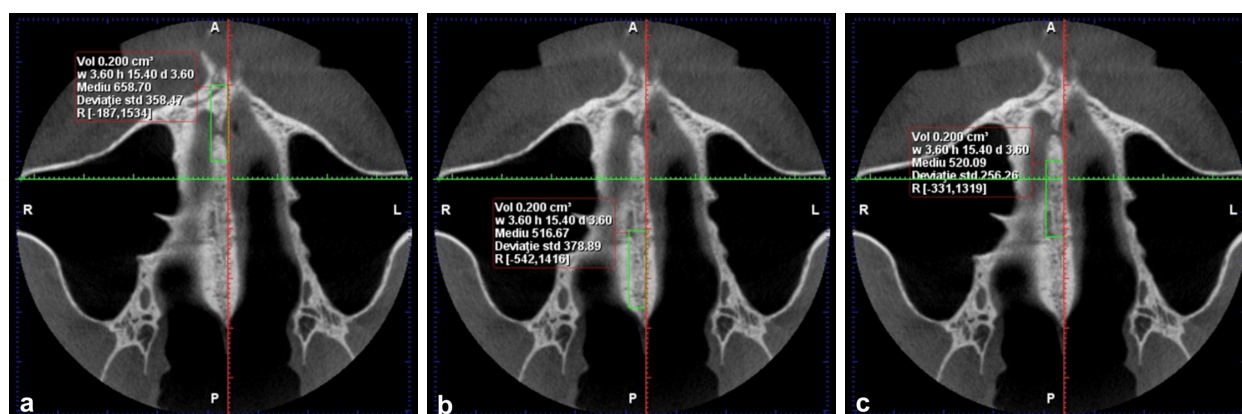

Figure 1 – (a–c) Axial section. Measuring average bone density at the midpalatal suture before starting treatment in the three segments: anterior, middle and posterior.
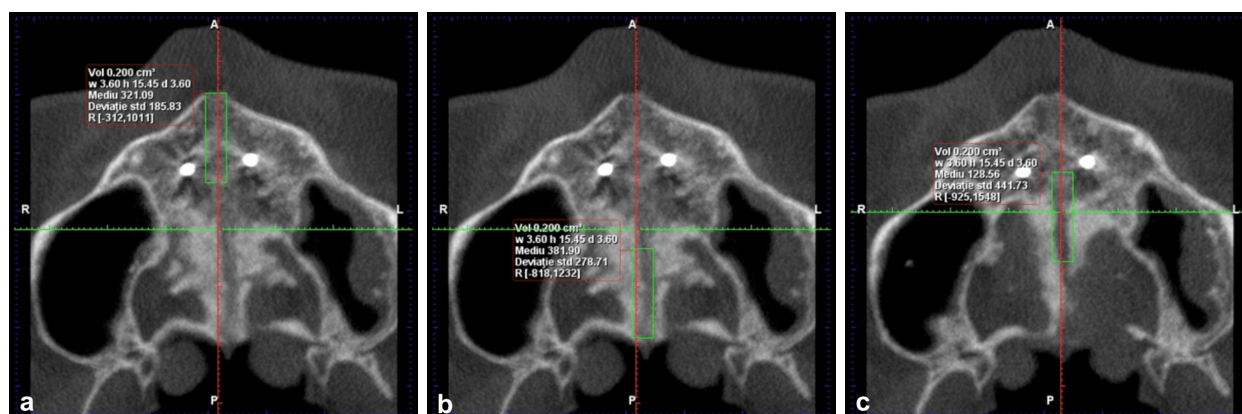

Figure 2 – (a–c) Axial section. Measuring average bone density at the midpalatal suture at the end of treatment in the three segments: anterior, middle and posterior.

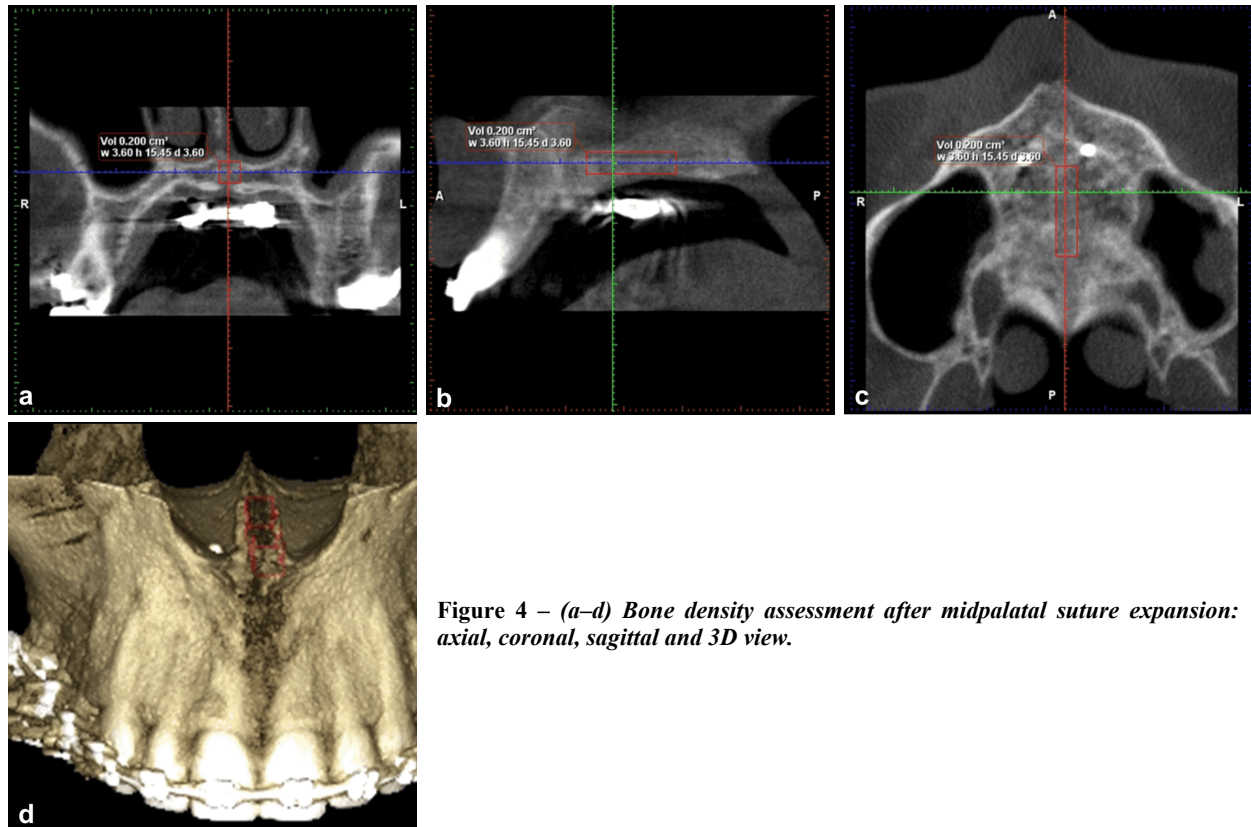Figure 3 – (a and b) Midpalatal suture aspect after expansion and initial aspect in 3D reconstruction.

Figure 4 – *(a–d) Bone density assessment after midpalatal suture expansion: axial, coronal, sagittal and 3D view.*
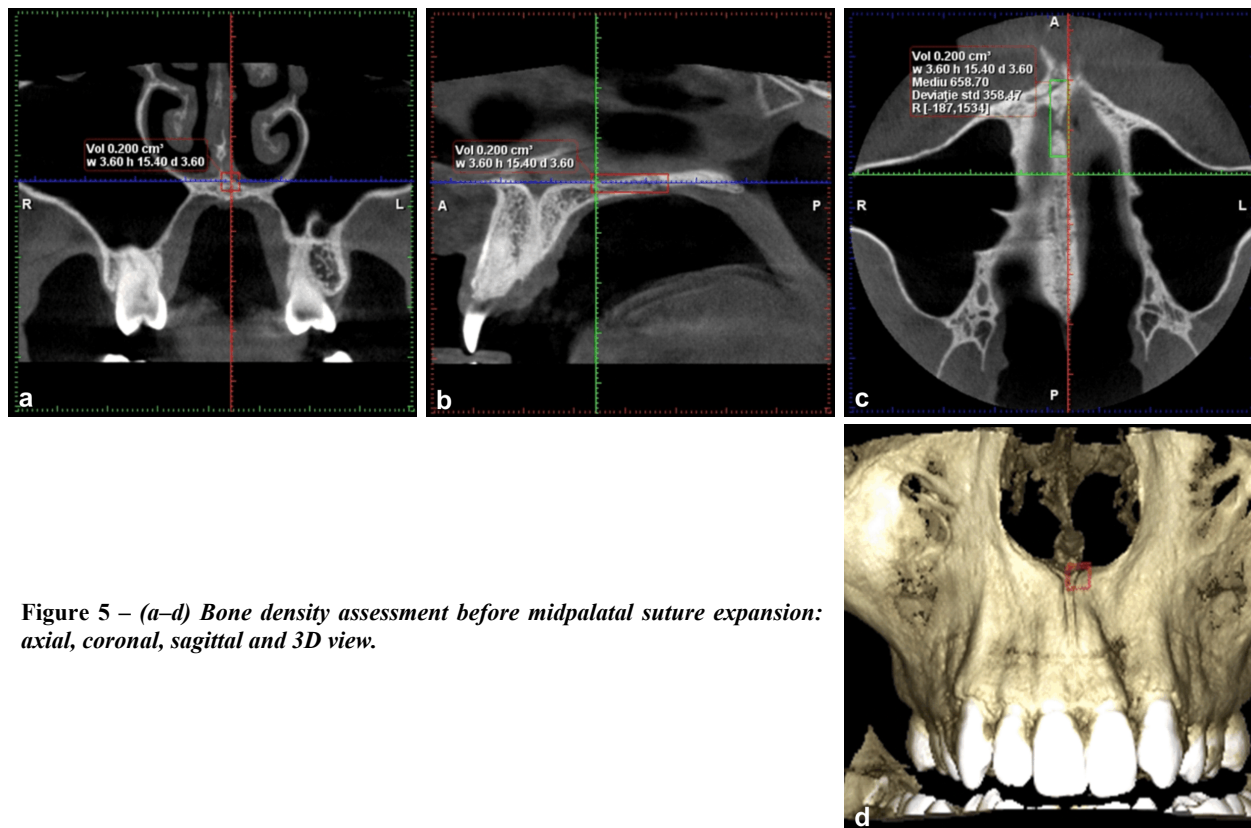

Figure 5 – *(a–d) Bone density assessment before midpalatal suture expansion: axial, coronal, sagittal and 3D view.*

Table 1 – *Bone density before midpalatal suture expansion*

	Anterior segment	Middle segment	Posterior segment
Women	658.7 HU	520.09 HU	516.67 HU
Men	672.9 HU	546.32 HU	529.78 HU

HU: Hounsfield units.

Table 2 – *Bone density after midpalatal suture expansion*

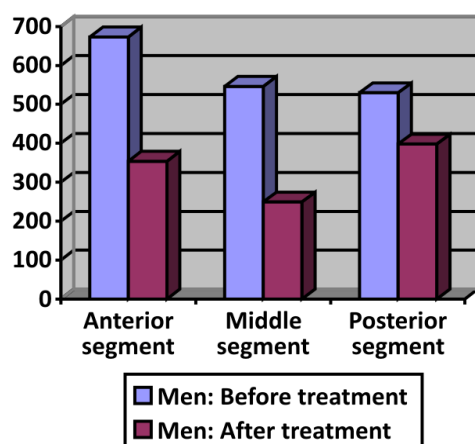|	Anterior segment	Middle segment	Posterior segment
Women	321.09 HU	128.56 HU	381.9 HU
Men	354.24 HU	249.35 HU	398.07 HU

HU: Hounsfield units.

Figure 6 – *Bone density variation before and after midpalatal suture expansion in the male group.*
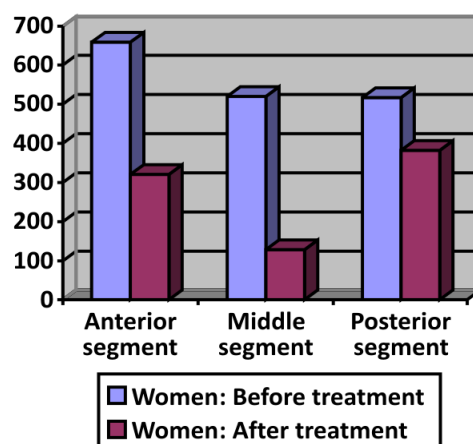

Figure 7 – *Bone density variation before and after midpalatal suture expansion in the female group.*
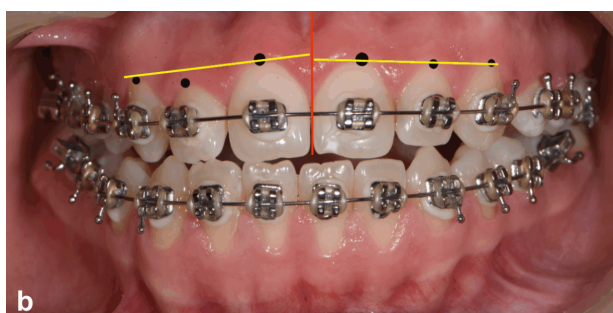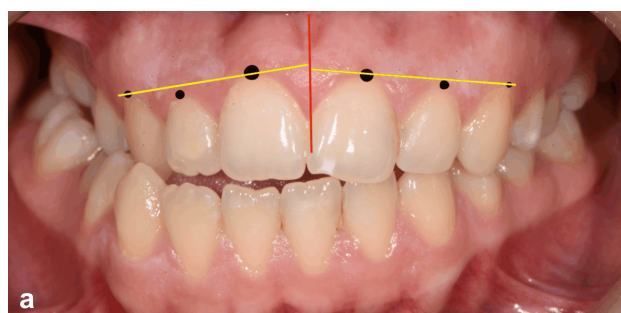

Figure 8 – *(a and b) Aesthetic parameters before and during orthodontic treatment, frontal view.*

Table 3 – *GAL line of hemiarcade 1: GAL classes (h1) of patients enrolled in the study before orthodontic treatment*

		Frequency	Percent	Percentage valid	Percentage cumulative
	Class I	10	26.3	26.3	26.3
	Class II	19	50	50	76.3
Valid	Class III	7	18.4	18.4	94.7
	Class IV	2	5.3	5.3	100
	Total	38	100	100	

GAL: Gingival aesthetic line; h1: Hemiarcade 1.

Table 4 – *GAL line of hemiarcade 1: GAL classes (h1) of patients enrolled in the study after orthodontic treatment*

		Frequency	Percent	Percentage valid	Percentage cumulative
	Class I	21	55.3	55.3	55.3
Valid	Class II	14	36.8	36.8	92.1
	Class III	3	7.9	7.9	100
	Total	38	100	100	

GAL: Gingival aesthetic line; h1: Hemiarcade 1.

Table 5 – *GAL line of hemiarcade 2: GAL classes (h2) of patients enrolled in the study before orthodontic treatment*

		Frequency	Percent	Percentage valid	Percentage cumulative
	Class I	12	31.6	31.6	31.6
	Class II	11	28.9	28.9	60.5
Valid	Class III	14	36.8	36.8	97.4
	Class IV	1	2.6	2.6	100
	Total	38	100	100	

GAL: Gingival aesthetic line; h2: Hemiarcade 2.

Table 6 – *GAL line of hemiarcade 2: GAL classes (h2) of patients enrolled in the study after orthodontic treatment*

		Frequency	Percent	Percentage valid	Percentage cumulative
	Class I	29	76.3	76.3	76.3
	Class II	5	13.2	13.2	89.5
Valid	Class III	3	7.9	7.9	97.4
	Class IV	1	2.6	2.6	100
	Total	38	100	100	

GAL: Gingival aesthetic line; h2: Hemiarcade 2.

⬚ Discussions

Compression of the upper jaw or jaw deficiency in the transversal plane along with the presence of a deep palate represent a skeletal development syndrome that causes breathing problems with a negative impact on dento-facial development. Rapid jaw expansion is the traditional method of choice used to treat this syndrome.

There have been many attempts to determine the correlation between the age of the patient, the degree of maturation of the midpalatal suture and the determination of the type of expansion indicated for each case but not so many focused on differences between males and females. Results obtained in the current study did not show significant differences between the male and female groups regarding the measured parameters. No precise clinical guidelines on the type of treatment for maxillary expansion, surgical or non-surgical, have been established. Schlegel *et al.* found that a 23-year-old young presented suture ossification while an older subject showed less ossification [15]. Similarly, Persson & Thilander reported

that midpalatal sutures may become ossified during the teenage period, but a marked closure is rare before the age of 30 [16].

CBCT images were examined made in different incidences: coronal, sagittal, axial and 3D, both concurrently and separately. Angelieri *et al.*, proposed the assessment of suture morphology using CBCT images [12]. However, the position of the cross-section may be cause to some limitations given that if the cross-section is not positioned correctly in the midpalatal suture, the specialist may misinterpret the CBCT image.

In this study, it was established that maxillary expansion takes place in the anterior portion of the palate, the middle and posterior portions by comparing the bone density values in the three segments before and after the maxillary expansion. Research in the field showed that only 5% of sutures are closed by 25 years, and 5% of suture closures can be broken without a corticotomy [4]. In a more recent study, Korbmacher *et al.* concluded that the suture closure index was generally low, with a variation between individuals, and was not in correlation with chronological age [17]. In our study, measurements showed an increased bone density in the anterior and middle segments in both groups prior to the start of the treatment.

An opening of the palatine suture in the triangular shape with a large base to the anterior portion of the jaw has been observed. The medio-palatine suture extends across the entire anterior surface of the palate to the posterior, and this anatomy should allow its opening evenly and parallel in all three segments: anterior, middle and posterior. This is not possible, however, and the posterior portion suffers a minimal displacement, as the palate is articulated with the medial and lateral sphenoid bone processes. Repair of the bone area is required in order to have stable results. However, there are no guidelines in literature that relate to the retention period required for the bone suture to repair [18–21].

The progression of the contour from incisors to canine is an important factor in smile aesthetics. The GAL is a classification designed to ensure a pleasant transition of the gingival level between the anterior maxillary teeth. It is defined as a line joining the tangents of the zeniths of the free gingival margin of the central incisor and canine. The GAL angle is formed at the intersection of this line with the maxillary dental line. In our study, we found a significant reduction in the number of class II, class III and class IV and an implicit increase in the number of GAL I class from baseline 22 to 50. Class II declined from a total of 30 before orthodontic treatment at 19 years after orthodontic treatment, and class III from 21 to 6, followed by class IV from 3 to 1. All of these changes were statistically significant similar to those found by Seixas *et al.* in a study conducted in 2012 [22].

⊟ Conclusions

Bone density along the maxillary suture plays an important role in the success rate of orthodontic treatment. For this reason, it is important to evaluate it before starting treatment and correlate it with the characteristics of the patient so that the correct decision regarding expansion could be made. Assessing the palatal suture maturation on CBCT images is a very promising predictor for conventional or surgically assisted jaw expansion. This allows the clinicians to formulate a correct diagnosis and plan a proper individualized treatment for each individual case. The distribution of the gingival height in terms of the classes found prior to the orthodontic treatment remained unchanged after its completion. In the study, there was a significant reduction in the number of class II, class III and class IV and an implicit increase of GAL I class that ensure a pleasant transition of the gingival level between the anterior maxillary teeth.

Conflict of interests

The authors declare that they have no conflict of interests.

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