

Digital radiographic evaluation of the midpalatal suture in patients submitted to rapid maxillary expansion

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ABSTRACT

Aims: To analyze the density of the midpalatal suture by means of digital radiographs three months after retention to evaluate if this period of retention is really sufficient for bone repair.

Materials and Methods: This prospective study consisted of 31 patients (11 girls and 20 boys) in the mixed or permanent dentition stage, treated using a tooth-tissue borne expanders (Haas). Occlusal digital radiographs were taken at three stages: prior to rapid maxillary expansion (Stage I); immediately after desired maxillary expansion (Stage II); and after three months of retention (Stage III). Radiographs were taken on a dental X-ray machine, set at 70 kVp and 7 mA with an exposure time of 0.04 s. A phosphor storage plate system, imaging plate size n. 2 (35 × 45 × 1.6 mm), was used. Three regions (A, B and C) measured 0.02 mm² were selected for optical density analysis. The difference between the measurements was evaluated with the paired t-test.

Results: The optical density was reduced at Stages II and III compared with Stage I. Between-stage comparison showed statistically significant changes for all variables ($P < 0.05$), with the highest mean optical density at Stage I and the lowest at Stage II, in all groups. Actually, there was an increase in optical density between Stages II and III, but they are reduced compared with Stage I.

Conclusion: The results strongly suggest that bone formation did not occur as expected, and that a longer retention period for bone repair may be necessary.

Key words: Digital radiograph, new bone formation, rapid maxillary expansion

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Maxillary transverse deficiency is one of the most pervasive skeletal problems in the craniofacial region.^[1] It is a dentofacial disturbance characterized by the presence of uni- or bilateral posterior crossbite, deep or high-arched palate, tooth crowding, dental tipping, dark spaces in the buccal corridors and/or difficult nasal breathing.^[2] As part of an initial evaluation of a patient, McNamara^[1] recommended that the distance between the closest points of the upper first molars (ie., transpalatal width) should be measured. According to this author^[1] and colleagues,^[3] typically a maxillary arch with a transpalatal width of 36 to 39 mm can accommodate a dentition of average size

without crowding or spacing, whereas maxillary arches less than 31 mm in width may be crowded and thus in need of orthopedic or surgically assisted expansion. Evidently, other factors, such as facial type, soft tissue profile, and level of muscle tonus, also must be taken into consideration when making the expansion decision. Routinely orthodontists correct these deficiencies with orthopedic rapid maxillary expansion (RME) appliances that separate the maxillary suture and create skeletal orthopedic expansion.^[4] According to Podesser *et al.*,^[5] during RME the anterior part of the midpalatal suture opens more than the posterior, thus also creating an arcial movement in the horizontal plane. In the course of the treatment, the patient is instructed to activate the screws one-quarter turn twice a day. The activation time varied according to individual needs. Moreover, a retention period of three to six months is recommended to allow the reorganization and stabilization of the maxillary suture after rapid expansion because immature newly formed bone can lead to relapse.^[6-8]

Although conventional rapid maxillary expansion (RME) can be used in younger patients, the facial suture lines become significantly more interdigitated and become either partially or totally fused as individuals' age. After

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sutural closure or completion of transverse growth, orthopedic transverse maxillary expansion is largely unsuccessful because the expansion is primarily composed of alveolar or dental tipping with little or no basal skeletal movement.^[9]

The analyses of bone maturation at the suture certainly would help in adequate treatment planning and post-treatment control.^[10] Oral radiographs are still widely used as the main diagnostic method to assess alterations in mineralized tissues during orthodontic treatment. Indeed, occlusal radiographs had been essential to analyze the midpalatal suture throughout rapid maxillary expansion.^[11] This suture appears on occlusal radiographs as a narrow radiolucent line image, that becomes wider and separated immediately after RME.^[2]

The search for higher imaging quality and diagnostic accuracy, as well as the desire to make the use of ionizing radiation as safe as possible, has led to the development of digital radiographic equipments and innovative ways of acquiring intraoral radiographic images.^[12] Among other advantages over conventional film, digital radiographs enable electronic manipulation of the images to perform measurements, density corrections and to enhance contrast and brightness.^[13-15]

A radiographic analysis of bone maturation at the suture by means of digital images is based on the detection of differences in density, which represent alterations in bone mineral content. Density measurements provide a wider range of grayscale levels from 0 to 255 (from black to white) while the human eye can only distinguish 28 to 32 shades.^[16,17] Consequently, digital images enable to distinguish smaller alterations in bone than human eyes when analyze a conventional film-based occlusal radiograph.

Evaluation of new bone formation by optical density analysis of digital radiographs is a great source of post-operative treatment control. According to Sannomiya *et al.*,^[2] using this measurement, it is possible to quantify new bone formation in the reference area to control the ossification process. For this reason, the aim of this study is to analyze the density of the midpalatal suture by means of digital radiographs prior to RME, immediately after it and three months after retention, to evaluate if this period of retention is really sufficient for bone repair.

MATERIALS AND METHODS

This study is in accordance with the Helsinki Declaration of 1975 and it had the approval of the Ethical Committee of author's university (approval number 13400). An informed consent was obtained from the parents or guardians of all subjects.

This prospective study consisted of 31 patients (11 girls and 20 boys) in the mixed or permanent dentition stage (average age: 11 years 6 months, minimum: 7 years 5 months, maximum: 15 years 10 months). The criteria for the selection were as follows:

- skeletal maxillary arch deficiency,
- bilateral posterior crossbite,
- adequate clinical crown length so as to provide sufficient anchorage for the RME appliance, and
- no missing teeth in the upper dental arch.

The sample was treated using a tooth-tissue borne expanders (Haas) as the initial part of comprehensive orthodontic therapy. The appliance screw underwent a standardized protocol of expansion with two quarter turns twice a day, corresponding to 0.8 mm of daily expansion, until the necessary amount of expansion to correct the transverse maxillary deficiency was achieved, namely until the maxillary palatal cusps are in contact with the mandibular buccal cusps to balance the relapse. The average amount and duration of expansion were 8.5 ± 1.2 mm and 10.0 ± 2.0 days, respectively. Subsequent to the active phase, the appliance was left in situ as a passive retainer for a further three-six months [Figure 1].

Maxillary occlusal radiographs were taken for patients at three treatment stages using a Trophy Elitys dental X-ray machine (Trophy Radiologie, French), set at 70 kVp and 7 m A with an exposure time of 0.04 s. The Digora phosphor storage plate system (Soredex, Finland), imaging plate size n.2 ($35 \times 45 \times 1.6$ mm), was used. For standardized achievement of occlusal radiographs from the region of maxillary central incisors, a film holder specially designed for this study was used. This apparatus allowed that a 9-cm focus-film distance had kept constant for achievement of all occlusal radiographs during the study, with standardized vertical (65°) and horizontal (0°) projections, independent of the patient's head orientation.

Occlusal digital radiographs were taken at three stages: prior to rapid maxillary expansion (Stage I); immediately after desired maxillary expansion, when the device was no longer activated (Stage II); and after three months of retention (Stage III).

Optical density analysis was standardized by delineation of areas and planes on the digital occlusal radiographic image. Three regions measured 0.02 mm^2 were selected for optical density analysis. Region A radiographically was located 3.0 mm from the alveolar bone crest between maxillary central incisors at the region of the midpalatal suture. Region B radiographically was located 6.0 mm from the alveolar bone crest between maxillary central incisors at the region of the midpalatal suture. Region C radiographically was located 3.0 mm forward from the splint RME device at the region of the midpalatal suture [Figure 2].

Optical density analysis was performed at areas A, B and C with the aid of the Digora for Windows software (version 2.1) at all Stages I, II and III. The material was measured twice by one examiner after a 15-day interval. Results after the two time periods were evaluated using kappa statistics to check intraobserver reproducibility. The value obtained for kappa was above 0.84.

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) and the results were shown as the mean $\pm$ 1 standard deviation (SD). The difference between the measurements was evaluated with the paired *t*-test and the level of statistical significance was $P < 0.05$.

RESULTS

Table 1 presents the measurements, ratio and standard deviations of optical density at each region and treatment stage. The optical density was reduced at Stages II and III compared with Stage I. Between-stage comparison showed statistically significant changes for all variables ($P < 0.05$).

The mean optical density values for all patients and per gender at the different phases are shown in Figure 3, with the highest mean optical density at Stage I and the lowest at Stage II, in all groups. Actually, there was an increase of 18.63% in optical density between Stages II and III, but they are reduced compared with Stage I.

DISCUSSION

RME is an accepted procedure in the treatment of maxillary transverse deficiencies and correction of crossbites with relief of dental crowding.^[18] However, the best time to perform palatal expansion is widely discussed. Normal development of the midpalatal suture occurs gradually by histological alterations with progressive decrease in function: increased sutural interdigitation and synostosis, from back to front and from mouth to nose.^[19]

The mechanical opening of the suture causes a series of histological changes that result in bone remodeling. This, in turn, leads to suture regeneration. Clinically, expansion

of the palate is achieved.^[20] In younger patients, more positive results after RME are observed because of the lower resistance of the midpalatal suture, greater flexibility of the skull and faster dissipation of forces.^[6,21] Irregularities and imbrications present in the suture do not clinically advise against RME, since it is the structural resistance of the middle face – especially caused by the zygomaticomaxillary

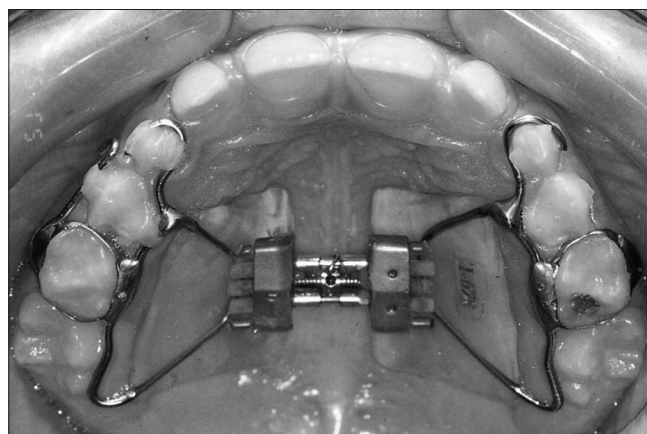


Figure 1: Orthodontic RME using haas device. Stage III as a passive retainer

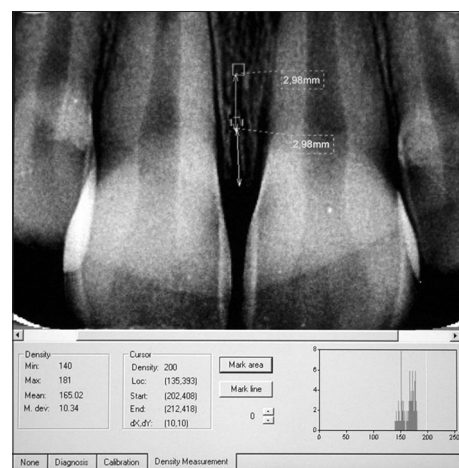


Figure 2: Optical density analysis (digora for Windows software interface)

Table 1: Measurements and standard deviations of optical density at all regions

Region	Stage	Mean	Ratio	SD
A	(I) Before expansion	131.51	1.00	32.00
	(II) After expansion	90.69	0.69	27.15
	(III) Retention	115.79	0.88	25.52
B	(I) Before expansion	148.67	1.00	30.68
	(II) After expansion	100.94	0.68	25.88
	(III) Retention	130.64	0.88	22.36
C	(I) Before expansion	181.43	1.00	18.73
	(II) After expansion	128.82	0.71	24.41
	(III) Retention	160.02	0.88	16.67

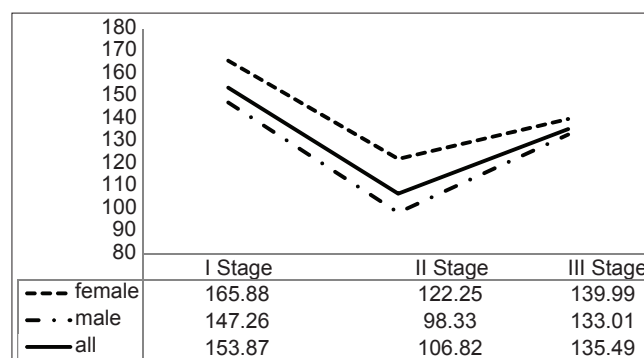


Figure 3: Mean optical density values for all patients and per gender at the different phases

and pterygomaxillary sutures – that anatomically hinders transverse expansion of the maxilla in older patients.

As the maxilla articulates superiorly and posteriorly with the rest of the midface, the midpalatal suture is opened in a 'V' shape during RME. The most anterior and inferior points move the greatest distance, with a fulcrum somewhere within the nasal airway.^[18]

Clinically it is observed by a temporary diastema between the upper central incisors, but it is most correctly confirmed by means of occlusal radiographic examination. The radiographic image will show a larger radiolucid area, parallel to the suture or triangular shaped, with its base toward the anterior region of the face. Subsequent radiographs must be obtained to assess new bone formation at the suture. The regeneration of the midpalatal suture, absence of remaining radiopaque cortical lines and mineralization similar to normal bone indicate the end of retention period.^[22]

Correct radiographic information guides therapy and its follow-up. Thus, standardization is necessary when acquiring the images, so that the radiographs obtained at different times are similar and can be compared to analyze the results of the treatment. Considering that changes in vertical or horizontal angles when taking the radiographs may cause irreversible image errors,^[23] a specially designed film holder was used in this study to standardize the focus-film distance and angles.

In digital imaging, measurement of the optical density-like (OD-like) of a selected area is extremely important. OD-like is represented by numerical values corresponding to minimum, maximum and average gray shades shown by the pixels in that area. The 8-bit system used for digital imaging displays a range of 256 gray tones. Although the human eye cannot discern many of them, the differences in gray value can be easily observed when expressed in numbers. Thus, the data may be quantified, making diagnosis easier and more accurate.^[16]

Utilization of optical density analysis in this type of procedure might allow better control in the retention period after rapid maxillary expansion. According to Sannomiya *et al.*,^[2] this kind of study could help orthodontists because there was an optical density pattern between onset and immediately after RME and after retention.

In this report, density measurements were analyzed in three different treatment phases. Mean OD-like values for all patients were analyzed, and the initial and final overall averages were different [Figure 3]. Reports of optical density in RME describe that the optical density values decrease after the procedure, but there is a tendency of return to the initial values before expansion.^[2] The final overall average was around 90% of the initial value obtained. This

difference was statistically significant ($P < 0.05$). The female group, in particular, had a lower OD-like final value, around 84% of the initial one. This can be explained by the fact that, although the female bone maturation occurs earlier than in males,^[24] the girls of the sample are still not at the pubertal growth peak; therefore, the osteogenic and maturation processes have not suffered hormonal influence and thus their tissue response is significantly slower compared to males. However, there is no statistic difference between the female and male groups in this study ($P > 0.05$).

The related literature is unanimous in advocating that a period of at least three months is necessary for bone repair.^[6,8] However, the results of the present study show that final density values after three months of retention are not similar to initial values. Only three patients presented radiographic characteristics similar to normality at the suture and maxillary bone, which indicated suture regeneration after three months of retention.

In conclusion, the results strongly suggest that bone formation did not occur as expected, and that a longer retention period for bone repair may be necessary. Furthermore, the digital radiographs may be a valuable tool to evaluate alterations in the midpalatal suture that occur during the RME treatment.

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