RESEARCH

Evaluation of optical density of the midpalatal suture 3 months after surgically assisted rapid maxillary expansion

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Objectives: This study evaluated new bone formation at the midpalatal suture after surgically assisted rapid maxillary expansion (SARME) by optical density analysis.

Methods: The study population consisted of 18 patients, 10 males and 8 females. All patients presented maxillary atresia with posterior crossbite and were submitted to SARME. Maxillary occlusal radiographs were taken at three stages (before SARME, immediately after SARME and after 3 months). Three patients did not attend the session at the 3-month period for achievement of the occlusal radiography and thus were excluded, leading to a final sample of 15 patients. Two regions were selected and analysed at each stage. Region A measured 8 × 1 mm² and was located 1.2 cm from the tangent to the maxillary central incisors at the region of the midpalatal suture. Region B measured 5 × 9 mm² and was located 4.3 cm from the tangent to the maxillary central incisors at the region of the midpalatal suture. An aluminium scale (step wedge) with eight steps varying from 1 mm to 8 mm was adapted at the end of the films. Radiographs were taken on a Spectro 70X machine (Dabi Atlante, Ribeirão Preto, Brazil) set at 70 kVp and 10 mA with an exposure time of 1.0 s. Radiographs were scanned using a Power Look 1000 scanner (Umax, Taiwan, China) and a computer Dimension E510 (Dell Computer, Taiwan, China). Optical density analysis was performed after digitization of radiographs using the software Image Tool (UTHSCSA, San Antonio, TX).

Results: Statistical analysis of region A revealed statistically significant differences between Stages I and II (P = 0.0001), Stages II and III (P = 0.0001) and Stages I and III (P = 0.0003). In region B, statistically significant differences were observed between Stages I and II, I and III and II and III (P = 0.0018, P = 0.0003 and P = 0.0003, respectively).

Conclusions: Optical density analysis improves post-treatment control of SARME procedures by surgeons and orthodontists. After 3 months, new bone formation at the midpalatal suture is not complete.


Keywords: radiograph, optical density, new bone formation

Introduction

Maxillary atresia or transverse deficiency is a dentofacial disturbance characterized by the presence of uni- or bilateral posterior crossbite, deep or high-arched palate, tooth crowding, dental tipping and difficult nasal breathing. The surgically assisted rapid maxillary expansion (SARME) is a clinical therapeutic procedure used to correct this deficiency. In adult patients, who have already completed ossification of the midpalatal suture, this treatment allows subsequent separation of the midpalatal suture by orthodontic devices fabricated and adapted for that purpose.¹ The midpalatal suture appears on occlusal radiographs as a narrow radiolucent line image. Immediately after rapid maxillary expansion, the radiolucent line of the suture becomes wider and separated. Cobo et al² emphasized that investigations into changes of the maxilla and midpalatal suture during rapid maxillary expansion are important for orthodontists to predict the effects of orthopaedic treatment. Analysis of new bone formation by
optical density analysis of digitized radiographs using an 
aluminium scale is a great source of post-operative 
treatment control. Using this measurement, it is possible 
to quantify new bone formation in the reference area to 
control the ossification process. Several studies3-5 have 
been published in the literature using optical density 
analysis. Scarparo et al3 presented a non-invasive method 
for bone density analysis at the mandible on periapical 
radiographs. An aluminium scale made with seven steps 
varying from 4.0 mm to 10.0 mm thickness was used as 
reference in the analysis. A specific software was developed 
(Densw) for optical reading of bone densities. The sample 
was composed of 34 pairs of radiographs with a view to 
compare bone density at both right and left sides of the 
mandible, considering the medium portion of the inter-
radicular septum of mandibular first molars. The study 
showed no statistically significant difference in bone 
density between right and left sides of the mandible. 
Simões4 performed a study with the objective of evaluating 
bone maturity using optical density measurement at 
the region of the midpalatal suture after SARME. In both 
studies, the authors agree that evaluation of bone maturity 
using optical density is a powerful tool for orthodontists and 
surgeons to control the results during and after SARME. 
This study investigated the bone density by optical 
density analysis immediately after SARME and 3 months 
after surgery.

Materials and methods
The present sample comprised 18 patients, 10 male 
patients and 8 female patients, aged 20–45 years old, 
assisted by graduate orthodontic students at São Paulo 
Metodista Dental School. All patients presented maxillary 
atresia with posterior crossbite and were submitted to 
SARME. The study was submitted to and approved by the 
Institutional Review Board of São Paulo Metodista 
University (protocol no. 67151/05). Patients were notified 
about the use of their data for research studies and signed 
an authorization for surgical procedures and utilization of 
data. The SARME standard procedure followed the same 
protocol of osteotomy of Le Fort I surgery, but without 
inclusion of the pterygopalatine suture and association 
with midsagittal maxillary osteotomy. Maxillary occlusal 
radiographs were taken of patients at three treatment stages 
using a Spectro 70X machine (Dabi Atlante; Ribeirão 
Preto, Brazil), set at 70 kVp and 10 mA with an exposure 
time of 1.0 s on 51 × 71 mm² occlusal films (Insight Film, 
Eastman Kodak, Rochester, NY). For standardized 
achievement of occlusal radiographs from the region of 
maxillary central incisors, a Rinn intraoral film holder 
(Rinn, Elgin, IL) was used. The focus–film distance was 
9 cm and was kept constant for achievement of all occlusal 
radiographs during the study, with standardized vertical 
and horizontal projections. An aluminium scale (step 
 wedge) with eight steps, varying from 1 mm to 8 mm, was 
adapted at the end of the films for optical density analysis. 
The first occlusal radiograph was taken before surgery and 
placement of the Hyrax expander (Stage I; Figure 1). After 

SARME, the Hyrax expander was activated until achieve-
ment of the desired opening. After the completion of screw 
activation, the second occlusal radiograph was taken 
(Stage II; Figure 2). The third radiograph was taken after 
3 months (Stage III; Figure 3). Three patients did not attend 

Figure 1 Pre-surgical radiograph

Figure 2 Radiograph taken immediately after surgery
this follow up visit and thus were excluded from the study. All radiographs were processed in the automatic processor Dent X (Del Grand; São Paulo, Brazil).

All radiographs were digitized using the Power Look 1000 scanner (Umax; Taiwan, China) and a computer Dimension E510 (Dell Computer; Taiwan, China), and saved in TIFF format at 300 dpi resolution. Each radiograph was analysed by histograms and compared with the aluminium scale using the Image Tool software (UTHSCSA; San Antonio, TX).

Optical density analysis was standardized by delineation of areas and planes on the digitized occlusal radiographic image. Two regions were selected for optical density analysis. Region A radiographically measured $8 \times 1 \text{ mm}^2$ and was located 1.2 cm from the tangent to the maxillary central incisors at the region of the midpalatal suture. Region B radiographically measured $5 \times 9 \text{ mm}^2$ and was located 4.3 cm from the tangent to the maxillary central incisors at the region of the midpalatal suture. Optical density analysis was performed at areas A and B and compared with the aluminium edge with the aid of the Image Tool software at all Stages I, II and III.

For the calculation of method error, the sample was re-measured at two moments, immediately after achieving radiographs and 20 days after the first measurement. Casual errors were calculated as suggested by Dahlberg, and systematic errors were evaluated by utilization of Bland-Altman graphs, characterized by tendency of increase or decrease in a measurement. Optical density was assessed by analysis of variance for repeated measurements, supposing a zero matrix of non-structured correlations with a factor stage for each measured region. The Bonferroni correction for multiple comparisons was used to evaluate at which stages there were changes in optical bone density. Tests were performed at a significance level of 5%. Assessing the study variables, the Kolmogorov–Smirnov test was used to present the normal distribution. The paired t-test was used for analysis of regions “A” and “B”.

Results

Measurement errors at each stage and region, as calculated by the Dahlberg formula, are shown in Table 1. Figures 4 and 5 present the distribution of measurement errors with utilization of Bland-Altman graphs. Casual errors were only observed after the third decimal place, i.e. they were very small errors. There was no relationship between measurement errors that could characterize a systematic error, thereby constituting only small casual errors, as presented in Table 1, without clinical relevance. Calculation of intraclass correlation, which measures the agreement measurement for the systematic error, did not reveal agreement lower than 98%. Thus, measurements were highly concordant.

Table 2 presents the measurements 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, with observation of a larger reduction for region B compared with region A. Analysis of variance for repeated measurements revealed that both regions A and B presented a difference in mean optical density at Stages II and III compared with Stage I ($P = 0.0001$ for both).

Tables 3 and 4 present the results of the Bonferroni correction for multiple comparisons to evaluate at which stage there were changes in optical bone density at regions A and B, respectively. Table 3 demonstrates that all stages are different from each other in region A with regard to optical density, with the highest mean optical density at Stage I and the lowest at Stage II. There was an increase in optical density between Stages II and III. Table 4 demonstrates that the mean optical density at region B is different in nearly all stages, when the mean optical density is immediately reduced after surgery and is closer to the initial value with time.

Discussion

The orthopaedic–orthodontic treatment adopted for maxillary atresia when diagnosed and treated in young patients cannot be used in adult patients. Many studies

<table>
<thead>
<tr>
<th>Region</th>
<th>Stage</th>
<th>Casual error (Dahlberg’s formula)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I</td>
<td>0.0053</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>0.0050</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>0.0066</td>
</tr>
<tr>
<td>B</td>
<td>I</td>
<td>0.0061</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>0.0061</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>0.0079</td>
</tr>
</tbody>
</table>
emphasize that SARME is performed when there is enough ossification of the midpalatal suture in adult patients.

According to Krebs,\(^7\) posteroanterior separation of the maxilla after expansion is V-shaped, with wider separation at the anterior area compared with the posterior. It was noted in this study that in most cases, suture separation was V-shaped with the largest diastema between the central incisors.

The retention period after maxillary expansion, \(i.e.\) maintenance of the appliance in the mouth, is very controversial, even though its need is unquestioned, since the immediately expanded bone tissue presents highly vascular disorganized connective tissue, which is later replaced by immature bone tissue. This retention period to assure stability should be at least 3 months, according to authors Bell,\(^8\) Bishara and Staley\(^9\) to allow reorganization and stability of maxillary sutures submitted to rapid expansion.

Utilization of occlusal radiographs is adequate for evaluation of new bone formation at the midpalatal suture separation.\(^5\)

Optical density analysis with digitized occlusal radiographs and the aluminium step wedge were used as an advantageous and highly accurate method for bone formation and mineralization of the midpalatal suture after SARME, as revealed by Cobo et al.,\(^2\) Hildebolt,\(^10\) Scarparo et al\(^3\) and Vardimon et al.\(^11\)

Selection of the size and location of region A between the central incisors at the region of the midpalatal suture was based on its importance for surgical stability, according to Person and Thilander.\(^12\) Size and location of region B more posteriorly were used to allow distance from the expanding appliance, which would interfere with the optical density outcome. Studies conducted by Vardimon et al.\(^11\) revealed increased optical density at the posterior region after maxillary expansion.

Reports of optical density in rapid maxillary expansion describe that the optical density values decrease after the procedure, but there is a tendency of return to the initial values before expansion.\(^13,14\) In the present study, a decrease in optical density at the post-surgical stage
Optical density after SARM:

1. Observations were made of the mean values in regions A and B, namely 0.66 mm and 1.17 mm aluminum equivalent (Table 2), but after 3 months (Stage III) these values increased, with mean values of 0.89 mm and 1.88 mm aluminum equivalent (Table 2), in accordance with the aforementioned authors. The values at Stages II and III at regions A and B increased, with mean values of 1.14 mm and 2.97 mm aluminum equivalent (Table 2), but after 3 months (Stage III) these values increased, with mean values of 1.17 mm and 1.88 mm aluminum equivalent (Table 2), in accordance with the aforementioned authors. The values at Stages II and III at regions A and B increased, with mean values of 1.80 mm and 1.09 mm aluminum equivalent (Table 2), respectively.

2. Table 3 presents the result of the Bonferroni correction for multiple comparisons for region A.

3. Table 4 presents the result of the Bonferroni correction for multiple comparisons for region B.

4. On the other hand, Simões4 investigated a sample of subjects aged 6–11 years submitted to rapid maxillary expansion by orthopaedic expanding appliances, who presented earlier new bone formation at the anterior region compared with the posterior region. These data disagree with the present study, since according to Sandikcioğlu and Hazar15 the patient’s age and type of rapid maxillary expansion may lead to earlier new bone formation at the anterior region. The present study sample was composed of adult patients submitted to SARM. The present study revealed higher increase in optical density at the posterior region (B) compared with the anterior (A) as demonstrated in Tables 3 and 4, confirming the posteroanterior closing pattern (like a “zip”) of the midpalatal suture.

5. One of the great problems of SARM is the retention period to avoid relapse, which might impair the orthodontic treatment. Thus, the expander should be kept for retention until there is new bone formation at the expanded region. Few studies1,2 have been conducted to verify whether the new bone would be sufficiently mature to assure treatment stability. Utilization of optical density analysis in this type of procedure might allow better control in the retention period after rapid maxillary expansion.13,14 The present study could help orthodontists because there was an optical density pattern between onset and immediately after SARM and after 3 months. Moreover, this methodology may be applied in the daily routine of orthodontists to control new bone formation after SARM, since a simple methodology is used with aid of an occlusal radiographic film, an aluminium step wedge and a program for optical density analysis.


