Effect of a low-level laser on bone regeneration after rapid maxillary expansion

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Introduction: In this study, we evaluated the effects of a low-level laser on bone regeneration in rapid maxillary expansion procedures. Methods: Twenty-seven children, aged 8 to 12 years, took part in the experiment, with a mean age of 10.2 years, divided into 2 groups: the laser group (n = 14), in which rapid maxillary expansion was performed in conjunction with laser use, and the no-laser group (n = 13), with rapid maxillary expansion only. The activation protocol of the expansion screw was 1 full turn on the first day and a half turn daily until achieving overcorrection. The laser type used was a laser diode (TWIN Laser; MMOptics, São Carlos, Brazil), according to the following protocol: 780 nm wavelength, 40 mW power, and 10 J/cm² density at 10 points located around the midpalatal suture. The application stages were 1 (days 1-5 of activation), 2 (at screw locking, on 3 consecutive days), 3, 4, and 5 (7, 14, and 21 days after stage 2). Occlusal radiographs of the maxilla were taken with the aid of an aluminum scale ruler as a densitometry reference at different times: T1 (initial), T2 (day of locking), T3 (3-5 days after T2), T4 (30 days after T3), and T5 (60 days after T4). The radiographs were digitized and submitted to imaging software (Image Tool; UTHSCSA, San Antonio, Tex) to measure the optic density of the previously selected areas. To perform the statistical test, analysis of covariance was used, with the time for the evaluated stage as the covariable. In all tests, a significance level of 5% (P < 0.05) was adopted. Results: From the evaluation of bone density, the results showed that the laser improved the opening of the midpalatal suture and accelerated the bone regeneration process. Conclusions: The low-level laser, associated with rapid maxillary expansion, provided efficient opening of the midpalatal suture and influenced the bone regeneration process of the suture, accelerating healing. (Am J Orthod Dentofacial Orthop 2012;141:444-50)

Rapid maxillary expansion is a commonplace therapeutic practice in orthodontics.1-3 The lateral repositioning of the maxilla, with an increase in bone mass in the center, promotes marked changes in the morphology of the maxillary arch,4 leading to irrefutable advantages in the mechanotherapy of transverse maxillary deficiencies.2-5 Evidence of this movement can easily be observed in occlusal radiographs of the maxilla.6

Several studies have confirmed that low-level lasers can speed bone regeneration of the midpalatal suture in rapid maxillary expansion procedures,7-9 in addition to stimulating the synthesis of collagen, which is mainly responsible for the osteoid matrix.10 However, some authors have commented on the need for further studies to elucidate the action mechanism of infrared rays and their conditions of use in patients, since the protocols of laser use are contradictory in the literature.7-9,11-17

Several authors studied the effect of low-level laser irradiation on bone regeneration during expansion of the midpalatal suture.8,9,18 They concluded that the low-level laser significantly stimulated bone regeneration of the midpalatal suture during expansion, in addition to accelerating its opening.
Cobo et al and Sannomiya et al, among other authors, carried out studies using specific programs to evaluate optical density in the tracking of bone regeneration processes, based on sequential digitized radiographs, in which subtle differences in density can be determined, given by a histogram, representing differences in bone regeneration by comparing differences in density. Optical density is a gray scale, which varies from 0, representing absolute black, up to 255, which represents absolute white. For a more reliable evaluation of optical density, the use of an aluminum scale (step wedge) is recommended to calibrate the radiopacity of the radiograph.

Thus, the objective of this study was to evaluate the effects of a low-level laser on the midpalatal suture in rapid maxillary expansion procedures, by analyzing optical density and comparing a group of patients who underwent laser therapy with a control group who had rapid maxillary expansion without laser use.

**MATERIAL AND METHODS**

This project was submitted to the committee of ethics of the Methodist University of São Paulo, Brazil, and approved with protocol number 142.170/07.

We used 128 occlusal radiographs obtained from 27 patients who underwent rapid maxillary expansion, with a mean initial age of 10.2 years (range, 8.2-12.1 years). The subjects were selected randomly before the start of treatment and divided into 2 groups. The laser group (experimental) received rapid maxillary expansion with laser application; it included 14 patients (7 girls, 7 boys) with a mean age of 10.29 years. The no-laser group (control) had rapid maxillary expansion without laser application; it included 13 patients (6 girls, 7 boys) with a mean age of 10.22 years.

The radiographs were obtained at different times: T1, start (25 radiographs); T2, immediately after the expander appliance activations (25 radiographs); T3, 3 to 5 days after T2 (25 radiographs); T4, 30 days after T3 (26 radiographs); and T5, 60 days after T4 (27 radiographs). The number of radiographs varied because some patients were absent for taking the x-rays, but they did not have to be excluded from the sample.

The device chosen for expansion was a hyrax expander (DENTSPLY GAC International, Bohemia, NY), modified for the mixed dentition. This appliance consisted of a screw with a 13-mm opening capacity, loops on the permanent first molars, and contour on the deciduous molars and canines by means of a nickel-chromium wire soldered onto the loops on the lingual and buccal surfaces of the teeth, fixed by using light-cured resins and glass ionomer cement on the loops.

The activation procedure for the expansion screw was done according to the following protocol: 4 activations on the first day (1 full turn) and 2 daily activations on the following days (half turn). Expansion was performed until the desired overcorrection was achieved, visualized clinically by the lingual cusp of the maxillary molars, in the direction of the buccal cusps of the mandibular molars. After the end of activation, which lasted approximately 8 days, the appliance was left on for another 90 days in the same position with a retaining function and was then removed to be replaced by an acrylic retainer plate.

The level of opening of the screws in both groups was evaluated by measuring 2 points located on each half of the screw on the central part. Measurements were taken before and after the activations by using a digital paquimeter (Mitutoyo, São Paulo, Brazil). To determine precisely the final opening of the expansion screw, these measurements were subtracted, based on the methodology already described by Hino et al.

The laser used was a diode (TWIN Laser; MMOptics, São Carlos, Brazil) with the following irradiation protocol: wavelength, 780 nm; spot area, 0.04 cm²; energy per point, 0.4 J; number of points, 10; total energy, 4 J; time per point, 10 seconds; power, 40 mW; and density, 10 J/cm², according to the security criteria for the use of the laser.

Application was done in points, distributed in 4 points anterior to the screw, 2 lateral points, the point closest to the midpalatal suture, and 4 points posterior to the screw, totaling 10 points around the midpalatal suture, as shown in Figure 1.

Applications were made in the following stages: 1, from the start of expansion screw activation until 5 days later; 2, immediately after the end of expansion.
for 3 consecutive days; 3, 7 days after stage 2; 4, 7 days after stage 3; and 5, 7 days after stage 4.

All radiographs were taken according to the same standardization described by Sannomiya et al.\textsuperscript{19} and Hino et al.\textsuperscript{22} with a step wedge, a scale made of pure aluminum, distributed homogenously along its entire structure, with 8 steps varying in thickness from 1 to 8 mm and fixed on the anterior border of the film, which served as a comparative densitometric reference (Fig 2).

The occlusal radiographs were digitized by using a scanner (PowerLook 1000; Umax, Taipei, Taiwan) with 300 dpi resolution. With the aid of an imaging software program (version 5.5; Adobe Photoshop, San Jose, Calif), 2 straight lines were drawn. The first (R1) was a straight line horizontal to the border of the film, touching and uniting the 2 halves of the expansion screw. The second (R2), drawn perpendicular to R1, was located at the center of the expansion screw, following the path of the midpalatal suture. After drawing the reference lines, the area of interest to be analyzed was delimited, named area A, and centered with R2 in the same slope as R1, measuring $21.3 \times 46.1$ pixels, or $1.8 \times 3.9$ mm, as shown in Figure 3.

The images were transferred to a computer and saved in JPEG format (300 dpi). The optical density software program (Image Tool; UTHSCSA, San Antonio, Tex) was used; it has been widely mentioned in the literature to aid in measuring the optical density of the area of interest through a histogram equivalent to the gray scale of the analyzed area.\textsuperscript{19,20,22}

After we defined the step to be measured from the area of the step wedge (SW), the values relative to the shades of gray of areas A and SW were submitted to a mathematical calculation to transform the units of measurement of shades of gray into millimeters and then obtain the optical density of the area of interest analyzed. This procedure was performed in all radiographs of both groups, so that the comparison could be made of bone regeneration in the midpalatal suture, regardless of the density of each radiograph. This was always done with the aluminum equivalent millimeters unit: the higher the value, the more bone is present in the area, characterized by a more radiopaque area in the radiograph.

Statistical analysis

Method error evaluation was carried out 30 days after the first measurement with 30\% of the sample. To verify intraexaminer system error, the paired $t$ test was used. To determine casual error, Dahlberg’s error calculation was used.\textsuperscript{25}

The Student $t$ test was used for comparing the laser and no-laser groups for the following characteristics: initial age, time between phases, and distances of the expansion screw.

RESULTS

The comparisons between the 2 groups showed statistically significant differences for times T3 to T2, T4 to T2, and T5 to T4. Analysis of covariance (ANCOVA) was used for this factor to be considered when the densities of the groups were compared. The covariable was the
time for the evaluated phase. In all tests, a significance level of 5% ($P < 0.05$) was adopted. All statistical procedures were executed by using Statistica for Windows (version 5.1; StatSoft, Tulsa, Okla).

The results of the evaluations of systematic error by paired $t$ test and casual error measured by Dahlberg’s formula are shown in Table I; there were minimal differences, not statistically significant, indicating the reliability of our methodology.

To compare the 2 sample groups, the means, standard deviations, and Student $t$ test results were taken of the characteristics shown in Table II, which shows that the initial ages of the patients in both groups were similar, as were the amounts of screw opening, both of which allowed us to make reliable comparisons of the groups.

Table III shows the means, standard deviations, and ANCOVA results of the optical density comparisons in all 5 radiograph times for both groups, demonstrating that at T1 the 2 groups were comparable, proving that the sample started with similar initial densities. At T2, T3, and T4, the densities between the groups were different. This indicated that bone regeneration took place differently, and then density became similar again at T5, even though the laser group had a higher mean density than the no-laser group (not statistically significant), indicating the reliability of our methodology.

To compare the 2 sample groups, the means, standard deviations, and Student $t$ test results were taken of the characteristics shown in Table II, which shows that the initial ages of the patients in both groups were similar, as were the amounts of screw opening, both of which allowed us to make reliable comparisons of the groups.

Table IV shows the means, standard deviations, and results of the Student $t$ test for the comparison of optical densities between the radiograph times of the laser and the no-laser group. For the laser group, the data showed a significant decrease in density during screw opening (T2-T1), a significant increase in density during the final evaluation period (T5-T4), and another increase in density in the regeneration period per se (T5-T2)—ie, from the moment the expansion screw opening stage was concluded. In the no-laser group, there was no statistically significant difference for density in any evaluated period.

**DISCUSSION**

The patients in the sample were selected for this study according to 1 criterion with respect to the sample, shown in Table II, considering age (similar between the groups), sex (distributed homogeneously between the groups), and even level of patient maxillary atresia, so that the necessary amounts of expansion screw opening were similar for both groups.24,26,27

In this study, during the active phase (approximately 14 days), the activation protocol called for 1 full turn of the expansion screw on the first day and a half turn on days 2 through 6, followed by a passive phase characterized by a period of bone remodeling (retention period), which for this study lasted approximately 90 days.4,5,27 At the end of this phase, the suture was completely ossified, as shown in Table IV, in which we can compare the initial and final optical densities (T5-T1). After the period of remodeling, the expander appliances were removed, and removable acrylic retainer plates were set, before the placement of the fixed appliances (brackets).2,3

Rapid maxillary expansion is characterized by midpalatal suture opening, from the anterior to the posterior nasal spine. The older the patient, the worse the prognosis. As the resistance of the suture increases, more den- toalveolar effects will occur, instead of skeletal ones, which usually is not the aim of the therapy. Another controversial point is the stability of the maxillary expansion. Studies have proved that 8 to 9 months of stabilization with the expander appliance are necessary until the midpalatal suture is completely ossified.2,3

Studies have confirmed that occlusal radiographs are an adequate tool to evaluate the opening of the midpalatal suture.6,19,22,27,28 They are simple to perform and can be used routinely in the clinical setting; this contributes to the clinical applicability of this experiment. As shown in Table II, we had difficulty in accurately standardizing the days of radiograph retrieval, resulting in the lack of some radiographs during the evaluation period. This can be justified by inconve- niences in the established protocol of radiograph times: the availability of the university’s radiology service, which depended on the standardization of the radiography technique and the need for 1 operator at the same place with the same radiography device, in addition to the availability of the patients and their parents. Because of these difficulties, instead of evaluating 135 radiographs as expected (5 radiograph times $\times$ 27 patients), we evaluated 128 radiographs, since some patients did
For this study, imaging software was used to evaluate optical density, based on the methodology used by several authors to measure the optical density of the area of interest, by using a histogram equivalent to the shades of gray of the analyzed area.19,20,22

Authors such as Saito and Shimizu,8 who evaluated the effect of laser on bone regeneration of the midpalatal suture after rapid maxillary expansion in rats, reported that the laser was more effective during the initial stages of bone regeneration. The laser, according to certain studies, can accelerate the opening of the midpalatal suture by stimulating osteoclast activity, which could reduce orthodontic movement—ie, the buccal movement of the supporting teeth, which is an undesirable effect of the procedure.18,21,28 During the T2 to T1 interval shown in Table IV, which represents the active expansion period, the laser group showed a significant decrease in density (−1.60), suggesting a reduction in bone level in the area, which demonstrates the opening of the midpalatal suture.18

Interpreting this same T2 to T1 interval, but now comparing the 2 groups (Table IV), we concluded that, in the laser group, the optical density in the midpalatal suture areas was statistically lower than in the no-laser group; this suggests facilitation in opening the midpalatal suture. This agrees with the results of Sasaki et al,18 who concluded that the laser accelerates the opening of the suture; we were able to confirm it by starting from a homogenous sample, with similar initial optical densities and amounts of screw opening.

For intervals T3 to T2 and T4 to T3, which comprised the first 30 days of regeneration, according to Table IV, the values had no statistically significant differences; ie,
bone regeneration took place in a similar manner between the groups. With regard to final bone regeneration, when interval T5 to T4 was evaluated in Table IV, the laser group showed remarkable regeneration, characterized by a higher optical density than it had shown up to that time (1.76) and which can be well observed in Figure 4, showing an optical density curve ascending steeply for the laser group. This agrees with the studies of authors who believe that laser accelerates bone regeneration.8,9,18,29-38

We also observed that this density was slightly higher than the initial density (T5-T1), even though there was no statistically significant difference for the values, meaning denser bone.12,17 The same did not occur with the no-laser group, which showed no statistically significant difference with a slightly lower final optical density than the initial density (T5-T1), perhaps requiring more time for total bone regeneration, even though it did not show statistical significance.

When we evaluated the interval T5 to T4 in Table IV, which compared the behavior of the 2 groups during the final bone regeneration stage lasting approximately 63 days and for all the period of bone regeneration (T5-T2), excluding T1, the laser group showed higher optical density values (1.76 and 2.07) than did the no-laser group (0.05 and 0.59). It can be seen in Figure 4, which suggests that both the laser applied at the start of the rapid maxillary expansion and during the first month of regeneration could be important for quicker bone formation at the site.8,9,18,29-38

With the results of this study, it was possible to demonstrate that the laser enabled improved opening of the midpalatal suture and led to improved bone regeneration, which can be helpful in preventing relapses and reducing retention times; this should be evaluated in further studies. The use of a low-level laser is easy to handle, painless, has no side effects, is financially affordable, requires a relatively short application time, and takes up little physical space. This makes it an interesting feature for the office, especially because of the benefits it can bring to patients.

**CONCLUSIONS**

Based on our methodology and the results we obtained, it can be concluded that a low-level laser associated with rapid maxillary expansion provided efficient opening of the midpalatal suture and influenced the bone regeneration process of the suture, accelerating healing.

**REFERENCES**