Effect of 810 nm Diode Laser Therapy on the Rate of Extraction Space Closure


ABSTRACT

Purpose: To determine if biostimulation using a 810 nm diode laser was capable of affecting the rate of extraction space closure during orthodontic treatment.

Materials and methods: Forty dental arches of patients above 17 years of age requiring bilateral first premolar extractions were exposed to a 810 nm diode laser with a power density of 3.97 W/cm² at 3 weeks intervals for total duration of 12 weeks during the space closure phase under direct anchorage using miniscrews. Space closure measurements were taken using digital calipers and the unpaired t-test was used to compare the differences between the experimental and control sides.

Results: The rate of orthodontic tooth movement was greater on the experimental side and the difference between the two sides was statistically significant (p < 0.001).

Conclusion: Biostimulation carried out using a 810 nm diode laser is capable of increasing the rate of extraction space closure in humans. Hence, it can be concluded that it is capable of increasing the rate of orthodontic tooth movement.

Keywords: Biostimulation, Diode laser, Space closure.

INTRODUCTION

Patients and orthodontists have vested interests in shortening the length of orthodontic treatment time. Recent reports of an increased rate of orthodontic tooth movement following phototherapy using low level laser settings have piqued orthodontists’ interest in the procedure. Limpanichkul et al have evaluated the effect of low level laser therapy (LLLT) on tooth movement in humans.

Mester’s work showed that laser application could provide a biostimulatory effect. Biologic response to laser dosage and energy density follows the Arndt-Schultz law. Research has proved that bone resorption is the rate-limiting step in tooth movement. Therefore, any procedure that potentiates osteoclastic activity is capable of increasing the rate of orthodontic tooth movement and hence decreasing the overall duration of orthodontic treatment.

The objective of this study was to determine the effect on 810 nm diode laser on the rate of extraction space closure.

MATERIALS AND METHODS

Sample Selection

Forty arches in 25 patients, above the age of 17 years, requiring bilateral extractions in the same arch were randomly selected for this study. They did not have any active dental disease. A signed informed consent for orthodontic treatment involving the microimplants (TADs) and biostimulation using 810 nm diode laser was taken. The study used a split mouth design with implant supported space closure. Temporary anchorage devices (TADs) (8 mm length, 1.5 mm diameter, BMK, Korea) were used as anchorage units. The space closure was carried out on 0.019” × 0.025” SS wires using closed coil NiTi springs with a constant force of 150 gm (Fig. 1).

The experimental side was exposed to biostimulation using 810 nm diode laser and the contralateral side taken as control. All irradiations were done by the same operator using 810 nm gallium-aluminum-arsenide (GaAlAs) diode laser (Creation, Italy). The laser irradiation was delivered with a power output of 2 W in a continuous noncontact wave mode. The laser beam was delivered using a round 0.8 cm diameter metal conductor held perpendicular to the mucosa. Experimental doses were delivered on the buccal, and palatal surfaces over an area of 2 cm² (Fig. 2).

The application dose (the amount of energy applied at any one given treatment) was 60 J on either side with energy density of 4.77 J/cm² and power density of 3.97 W/cm². The treatment dose/total energy dose was 480 J for this study.
divided into four applications of 120 J each with an inter-
appointment gap of 3 weeks. The experimental side was
irradiated for 30 seconds on either side on days 1, 21, 42
and 63.

Digital caliper measurements accurate to ±0.001 mm
were recorded on days 1, 21, 42, 63 and 84. The distance
between the contact points of the maxillary canine and
second premolar were measured on both sides. Each distance
was measured three times, and the mean value was used for
data computations by a single investigator who performed
all the measurements.

**Statistical Analysis**

Tooth movements were evaluated over four time periods:
days 1 to 21, days 22 to 42, days 43 to 63 and days 64 to
84. The unpaired t-test were used to compare the differences
between the experimental and control sides. All statistics were
performed using the SPSS statistical program, version 14.0.

**RESULTS**

The difference in the rate of extraction space closure between
the experimental and control side was statistically significant
(p < 0.05) using unpaired t-test (Table 1).

The difference in the rate of extraction space closure
between the experimental and control side for maxilla was
statistically significant and statistically nonsignificant for
the mandible using unpaired t-test respectively (Table 2
and Graph 1).

**Difference in Individual Time Periods**

**Maxilla**

The difference in the rate of extraction space closure in
maxilla on the experimental side was statistically significant
as compared to the control group only for readings between
43 and 63 days (3rd time period) using unpaired t-test with
a p-value 0.011 (Graph 2).
Effect of 810 nm Diode Laser Therapy on the Rate of Extraction Space Closure

Table 1: Comparison of tooth movements (mm + SD) between two groups in 33 arches using unpaired t-test

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number (sample)</th>
<th>Mean</th>
<th>SD</th>
<th>Unpaired t-test (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental side</td>
<td>33</td>
<td>2.11</td>
<td>0.67092</td>
<td>0.001*</td>
</tr>
<tr>
<td>Control side</td>
<td>33</td>
<td>1.56</td>
<td>0.68544</td>
<td></td>
</tr>
</tbody>
</table>

*Clinically significant

Table 2: Comparison of tooth movements (mm + SD) between two groups in maxilla and mandible using unpaired t-test

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number (sample)</th>
<th>Mean</th>
<th>SD</th>
<th>Unpaired t-test (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental side</td>
<td>18</td>
<td>2.19</td>
<td>0.66</td>
<td>0.012*</td>
</tr>
<tr>
<td>Control side</td>
<td>18</td>
<td>1.60</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental side</td>
<td>15</td>
<td>2.04</td>
<td>0.70</td>
<td>0.057</td>
</tr>
<tr>
<td>Control side</td>
<td>15</td>
<td>1.52</td>
<td>0.71</td>
<td></td>
</tr>
</tbody>
</table>

*Clinically significant

Mandible

The difference in the rate of extraction space closure in mandible on the experimental side was statistically significant as compared to the control group for readings between 43 to 63 days (3rd time period) and 64 to 84 days (4th time period) using unpaired t-test with a p-value 0.033 and 0.049 respectively (see Graph 2).

Gender

The results from the study showed that the difference in the amount of space closure between males and females for both experimental and control side in total sample size of 33 patients was statistically nonsignificant using unpaired t-test (Graph 3).

The readings for maxilla (sample size of 18 patients) (Graph 4) and mandible (sample size of 15 patients) (see Graph 4) were also statistically nonsignificant using unpaired t-test.

DISCUSSION

The present study aimed to compare the difference in amount of space closure between the experimental (laser biostimulation) and control side (without laser biostimulation) thus enabling us to compare the rate of tooth movement. Evaluation of space closure was done for 40 arches in 25 patients. Seven arches were rejected during the 84 days experiment due to implant failure.

The power for the study was calculated to be 99.96%. Power calculation was done for separate arches as well, for maxilla, it was 99.56% and, for mandibular arch, it was 97.83%.

Power analysis was done using equation:

\[ Η = \left( Z_{α/2} \sqrt{P(1-P_a)} + Z_{1-β} \sqrt{P_o(1-P_o)} \right)^2 / (P_a - P_o)^2 \]

- \( P_o \) = population proportion
- \( P_a \) = sample proportion
- \( α \) = significance level
- \( 1 - β \) = power

A wide range of applications for low power lasers has been proposed in dentistry in the areas of caries detection, teeth whitening, light curing of composite resins and other dental materials cements. Oral pain relief for aphthous ulcers or other dental pain, including TMD, and increased osseointegration of dental implants. In the field of orthodontics, laser therapy has been used to decrease orthodontic pain and increase bone deposition across the expanded mid-palatal suture.
Goldman\textsuperscript{21} in 1960s was the first to report the effect of lasers on biologic tissues. Mester et al\textsuperscript{22} concluded that energy densities in the range of 0.5 to 4 J/cm\textsuperscript{2} are most effective in triggering a photobiological response in the tissue. Van Breugel and Bär\textsuperscript{23} noted that the power density is more important than the total dose in initiating biomodulation. The most commonly available soft tissue lasers in the dental office have a wave-length of 810, 910 or 940 nm. The higher wavelengths give better soft-tissue cutting efficiency and produce more heat necessitating the use of a local anesthetic. The 810 nm laser is more gentle on the tissues and, hence, more frequently used. Since this laser is frequently present in dental offices and has been used on orthodontic patients and in the cheapest diode laser available, hence, this wave-length was used in our study. Also biostimulatory behavior of this laser at different setting has been validated.\textsuperscript{4} In this study, we used the soft tissue laser with a wavelength of 810 nm, in continuous wave mode with a power output of 2 W which delivered the laser doses with an energy density of 4.77 J/cm\textsuperscript{2} and power density of 3.97 W/cm\textsuperscript{2}.

Though, LLLT experiments indicate that interrupted modes can solicit a greater biostimulatory response than in its continuous wave counterpart.\textsuperscript{24} The laser was used in continuous mode and not in superpulsed and true pulsed mode because each pulse’s peak power generates hundreds or thousands of Watts resulting in ablation of tissue.\textsuperscript{25} The results of Doshi and Bhad\textsuperscript{4} had indicated significant biostimulatory effects on bone metabolism around this wavelength, whereas higher dosages had bioinhibitory effects.

Biostimulation laser therapy applications were delivered at 3 weeks intervals for 12 weeks. Though studies have shown that multiple applications of LLLT produce a greater response than a single dose\textsuperscript{18,26} because the cells are most readily modified during a specific phase of their cell cycle so increasing the likelihood that cells are irradiated during this window of susceptibility. However, increasing the frequency of LLLT applications also runs the risk of delivering an excess amount of exposure and inhibiting a reaction.\textsuperscript{27} The 3 weeks interval also coincides with normal orthodontic recall visits.

There was a statistically significant difference in rate of space closure between experimental as compared to the control side. The rate of tooth movement after 12 weeks on the experimental side showed an increase of 28.9% as compared to the control side. The increase was calculated out to be 0.5 mm/month on biostimulation. This suggests that closing of an extraction space closure of 6 mm with biostimulation gives a rate of 1.5 mm/month (instead of 1 mm/month on nonirradiated side), thereby reducing the total treatment duration by 2 months. Similar findings were reported by Kawasaki and Shimizu\textsuperscript{1} and Yoshida et al.\textsuperscript{5} They reported a 1.3-fold increase in movement in their experimental laser group over periods of 12 and 21 days in rats. Fujita et al\textsuperscript{28} also demonstrated a 1.5-fold increase in their irradiated group over only 7 days in rats.

In this 84 days study, a statistically significant increase in the extraction space closure on experimental side was observed in third time period for maxillary arch and third and fourth time period for the mandibular arch. This indicates an increase in the rate of tooth movement in later time periods. This is in accordance with a study carried out by Roberts,\textsuperscript{29} which concluded that when teeth are moved continuously in the same direction, the remodeling rate increases in compact bone immediately ahead of the moving tooth. This enhanced remodeling process is probably related to the regional acceleratory phenomenon (RAP) commonly noted in osseous wound healing.\textsuperscript{29}

Only one study has compared the rate of orthodontic tooth movement in the maxillary and mandibular arches.\textsuperscript{4} In the present study, the increase in the rates of tooth movement at 84 days was statistically significant in the maxillary arch but not in the mandibular arch. The probable reason for this is that the alveolar bone in maxilla is less dense than that of the mandible because it has higher ratio of cancellous bone to cortical bone. Furstman, Bermich and Aldrich\textsuperscript{30} also found that the tooth movement is faster in the maxilla with bone displaying a greater resiliency than the mandibular alveolar segment.

No study has compared the difference in rate of space closure between the genders. Our study compared the difference between genders and concluded that the differences were not statistically significant but clinically thought provoking. The rate of space closure was faster in females than males. The reason could be thought of as a result of more porous bone in females and hence more blood supply and more cellular count. Literature also supports the fact that female bones are usually smaller and more slender than their male equivalents.\textsuperscript{31}

Various studies have evaluated the effects of laser therapy on rate of orthodontic tooth movement. The majority of published research outcomes indicate an increase in the rates of orthodontic tooth movement;\textsuperscript{1,2,4,6,32} one report shows no difference after laser application,\textsuperscript{7} while two others concluded that lasers can negatively affect tooth velocity.\textsuperscript{2,3} From this study, it could be concluded that there was an increase in the rate of tooth movement after laser therapy. Direct comparisons between the present and previous studies is complicated by a number of factors which includes different laser parameters (laser wavelength, power and energy density, mode of application, number and time.
of laser application) and various animal models (dog, rabbit, rat, etc.). The forces to move teeth also differ across studies, as did the methods used for measuring movement.

It is also possible that differences could have emerged, if the study had been conducted over a longer period of time. Some studies reporting differences have been carried out over a period of months rather than weeks. Nevertheless, there have been studies conducted over shorter time periods that have shown differences in tooth movement associated with LLLT.

Interestingly, Kim et al also did not show a statistically significant difference in the rate of tooth movement between the LLLT group and control until the fifth week of their 8 weeks study. However, other groups have shown differences between the experimental and control groups after a few days. Much of this difference may be accounted for by the methods used for measuring tooth movement, but it also calls into questions the efficacy of LLLT during varying periods in treatment.

The study by Esnouf and Wright showed that 850 nm laser at 100 mW power incurs a significant reduction in intensity within the first millimeter of penetration, up to 66%.

CONCLUSION

When using an 810 nm diode laser at energy density of 4.77 J/cm² and power density of 3.97 W/cm² at dose applications of 120 J per application had statistically significant effect on the rates of tooth movement.

The effect of laser was more in the maxilla as compared to the mandible and, in both increase, was more pronounced in the later periods.

The females showed greater rate of tooth movement compared to males but the results were statistically non-significant.

This therapy had no side effect on vitality of teeth. Hence, it could be safely used in orthodontics. Still further research is needed to determine the effect of laser on space closure and to establish the parameters that will result in the greatest rate of movement.

REFERENCES


