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Effect of Photobiomodulation on Bone Formation Around Dental Implants Placed in Overprepared Sites: Micro CT Scan Study

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ABSTRACT

Background: osseointegration is a prerequisite for success of dental implants. Various biological and physical methods have been shown to enhance osseointegration. The aim of this study was to evaluate the effect of laser photobiomodulation on bone formation around dental implants.

Material and Methods: Six adult male sheep served as the sample for this study. On either side of the lower border of mandible, four implants were inserted. To accommodate an implant that was 8 mm long and 4 mm wide, the implant bed was made to measure 10 mm long and 4.8 mm wide. Photobiomodulation with a 940-nm diode laser was applied daily for the next seven days, targeting the periimplant area. The animals were sacrificed at 4, 8, and 12 weeks (two animals at each time point). The dissected specimens were radiographed by micro-CT scan to evaluate the amount of bone formation.

Results: At the three time points, the laser group should a statistically significant higher values of bone implant contact, bone volume, intersection surface, bone surface density trabecular number, and trabecular thickness (P<0.05). However, trabecular separation in the laser group was statistically significantly less than the control group (p<0.05).

Conclusion: Laser therapy enhance bone-implant contact and increase osteointegration. A randomized clinical trial is recommended to reach a solid evidence- based conclusion.

Keywords: Bone, Implant, Laser, Photobiomodulation, Osseointegration

INTRODUCTION

One of the most pressing demands for patients visiting dental clinics is tooth replacement. There are numerous treatment alternatives, however dental implants have become increasingly popular and are viewed as a crucial choice for tooth replacement[1].

Low level lasers are proving to be an effective treatment with several applications in dental procedures. There are several benefits to the low-level lasers (LLLT) like promoting blood cell adhesion, stabilizing the clot at the peri-implant interface, and stimulating the body's own healing processes, at the last lasers increase osseointegration[2,3]. One of the major benefits of LLLT is its ability to promote healing and reduce inflammation around the implant site. This is because lasers are able to penetrate deep into the tissues of the body, stimulating cells and tissues to grow and regenerate. Additionally, LLLT is believed to help reduce pain and discomfort associated with dental implant surgeries, making the recovery process much easier for patients. Other potential benefits of LLLT include improved bone density around the implant, faster healing times, and a reduced risk of infection. Overall, the use of LLLT in dental implant surgeries has been shown to be a safe and effective way to improve patient outcomes and ensure successful implantation[4].

Osseointegration, which is crucial for implant success, is the direct structural and functional link between the surface of a titanium implant and the structured essential bone under functional load[5]. Apart from implant design, there are several other factors that affect the osseointegration of low stability dental implants. One of the primary factors is the quality and quantity of bone present at the implant site. If the bone is too thin or deficient in volume, it can lead to poor implant stability, which can, in turn, impair osseointegration. Additionally, bone damage during implant placement can compromise the bone healing process and negatively impact implant stability. Another factor is the presence of systemic diseases or conditions that can affect bone metabolism, such as osteoporosis or diabetes. These factors can lead to compromised bone quality, which can affect osseointegration. Finally, smoking and poor oral hygiene can also impair implant stability and osseointegration. Smokers often have reduced bone quality and quantity, and they heal slower than non-smokers. On the other hand, poor oral hygiene can cause peri-implantitis, leading to implant failure. Through the use of microcomputer tomography, this study sought to compare the bone formation that occurred after dental implant placement in the lower border of the sheep mandible, the study left side enhanced with laser therapy to those that occurred under control[6].

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Various techniques have been explored in order to improve osseointegration in low stability dental implants. One such technique is the use of surface treatments to increase implant roughness, thereby enhancing bone to implant contact. This involves modifying the implant surface at the nanometer-level, through processes such as grit-blasting, acid-etching, and plasma spraying. Another technique is the use of biodegradable hydroxyapatite coatings that gradually release calcium ions, promoting bone formation at the implant site. Additionally, the use of growth factors and bone morphogenetic proteins has shown potential in enhancing osseointegration. These molecules promote bone formation and can be applied to the implant surface or incorporated into bone substitute materials. Moreover, the use of computer-guided implant placement has been found to improve implant stability and osseointegration, by ensuring optimal implant positioning and reducing trauma to the surrounding tissues during surgery. Together, these techniques provide various options for improving osseointegration in low stability dental implants[6].

This study was conducted to evaluate the effect of photobiomodulation with a 940-nm diode laser on bone formation and osseointegration of implants lacking primary stability.

MATERIAL AND METHODS

Six mature male sheep weighing 60–70 kg and aged 3–4 years served as the study's sample. The Hawler Medical University (Kurdistan, Iraq), where this study was filed and authorized, has an Ethics Committee on Animal Use that sets criteria for all experiments.

Each animal had eight implants (ACH MEDICAL, G-DIFF IBT), four on each side of the lower border. The implant bed was made to be 10 mm long and 4.8 mm wide so that it could accommodate an implant that was 8 mm long and 4.0 mm wide. Ketamine (22 mg/kg) and xylazine (0.2 mg/kg) injections intramuscularly were used to administer general anesthesia during the surgical procedure. A 5 cm submandibular incision was performed to expose the lower edge of the jaw after shaving, scraping, and draping.

Once the bone was exposed by reflecting and retracting the skin flap, the implant bed was ready with a minimum standard distance. A 2 mm initial drill (lance) was used to fracture the cortical bone in order to prepare the osseous implant site. We employed 1200 rpm while heavily irrigated the surgical site with a 0.9% sodium chloride solution to keep the surgical site cool and prevent local tissue necrosis from overheating.

For photobiomodulation therapy, a 940-nm diode laser (BIOLASE, USA) was employed. The laser device was applied at a distance with a direct technique from the implant and the implant beds and was employed as a continuous wave with a 0.3 W output power. Four locations were used to deliver photo biomodulation to the implants at a rate of 20s/cm2 with a minimum of 10 J/cm2 and 0.3 W of power. Prior to implant placement, the socket was targeted with laser treatment; following implant implantation, the laser treatment was applied to the implant's surface and the surrounding bone twice daily for the following seven days. Penstrep-400 LA, an animal antibiotic, and topanalgin plus 100ml, an analgesic administered intramuscularly, are used as post-operative drugs.

Two animals were slaughtered at each of the three time points—4, 8, and 12 weeks. The sheep were sacrificed after the appropriate amount of time had passed, and the mandibular bone was completely removed. The mandible was then separated from the surrounding soft tissue and fixed in 10% neutral buffered formalin. Then, the harvested bone samples were radiographed by micro-CT scan (Skyscan, Belgium) for bone implant contact ratio, bone volume, intersection surface, bone surface density, trabecular number, trabecular thickness, and trabecular separation.

The data were analyzed using SPSS (version 25.0). Student t test was used to measure the difference between control side and laser-treated sides. The level of significance was considered at $P \leq 0.05$.

RESULTS

At the three-time points, the dissected hemimandible of the laser group showed greater bone formation than the control group (Figure 1).

Table 1 shows the micro -CT bone parameters of the two groups at 4 -weeks. The laser group showed a statistically significant higher measurements than the control group, except trabecular separation which was statistically significantly less than the control group (Figure 2).

The bone implant contact ratio of the laser and control group was 55.177 (±1.206) % and 52.08 (±1.033) %, respectively. The bone volume of the laser and control group was 37.482(±8.785) mm^3 and 28.127(±2.032) mm^3, respectively. The bone trabecular thickness of the laser and control group was 0.27017(±0.038) mm and 0.1805(±0.012) mm, respectively. The trabecular separation of the laser and control group was 0.8224(±0.026) mm and 1.0165(±0.054) mm, respectively. The trabecular number/mm of the laser and control group was1.8037(±0.113)1.2451(±0. 158), respectively.

Table 2 shows the micro -CT bone parameters of the two groups at 8- weeks. Laser group showed a statistically significant higher measurements than the control group, except trabecular separation which was statistically significantly less than the control group (Figure 3).

The bone implant contact ratio of the laser and control group was 59.418 (±0.916) % and 56.377 (±0.953), respectively. The bone volume of the laser and control group was 58.767 (±2.578) mm^3 and 54.00(±2.212), respectively. The bone trabecular thickness of the laser and control group was 0.2738 (±0.0246) mm and 0.1779 (±0.011) mm, respectively. The trabecular separation of the laser and control group was 0.68967 (±0.019) mm and 0.8857 (±0.033) mm, respectively. The trabecular number/mm of the laser and control group was 2.639 (±0.168) and 1.6680 (±0.218), respectively.

Table 3 shows the micro -CT bone parameters of the two groups at 12 -weeks. The laser group showed a statistically significant higher measurements than the control group, except trabecular separation which was statistically significantly less than the control group (Figure 4).

The bone implant contact ratio of the laser and control group was 67.867 (±1.275) % and 59.775 (±1.615) %, respectively. The bone volume of the laser and control group was 93.99 (±19.518) $mm^3$and 64.355 (±10.714) mm^3, respectively. The bone trabecular thickness of the laser and control group was 0.364 (±0.0304) mm and 0.258 (±0.0204) mm, respectively. The trabecular separation of the laser and control group was 0.6369 (±0.0289) mm and 0.760 (±0.0340) mm, respectively. The trabecular number/mm of the laser and control group was 2.924 (±0.180) and 2.173 (±0.102), respectively.

DISCUSSION

To improve dental implant osseointegrations, several techniques have been devised. The techniques utilized to boost biostimulation include vibration and LLLT treatments, while mechanical techniques involve altering implant surfaces or coating them with medicinal substances[7-11].

Figure 1: Fresh specimen showing periimplant formation at 8-weeks. Top: control group, bottom: study group

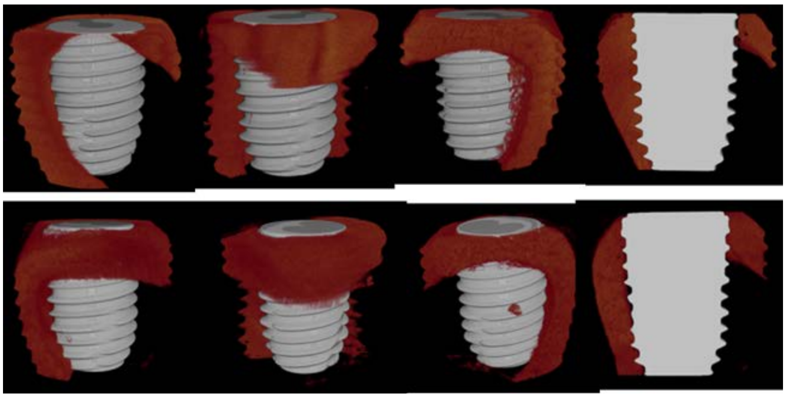

Figure 2: 3D Micro CT showing periimplant bone 4- weeks. Top: study group. Bottom: Control group

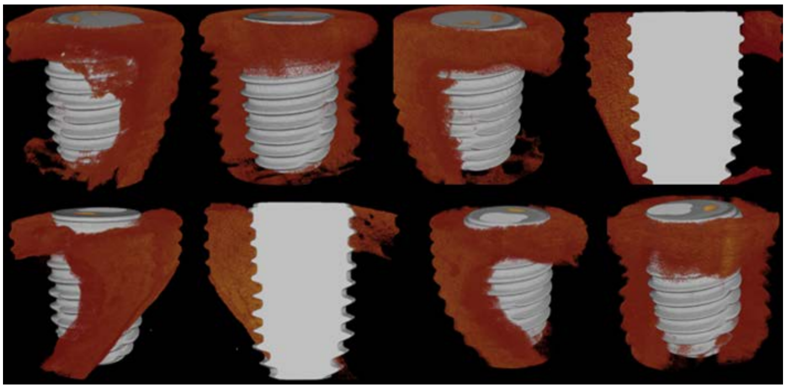

Figure 3: 3D Micro CT showing periimplant bone 8-weeks. Top: study group, bottom: control group

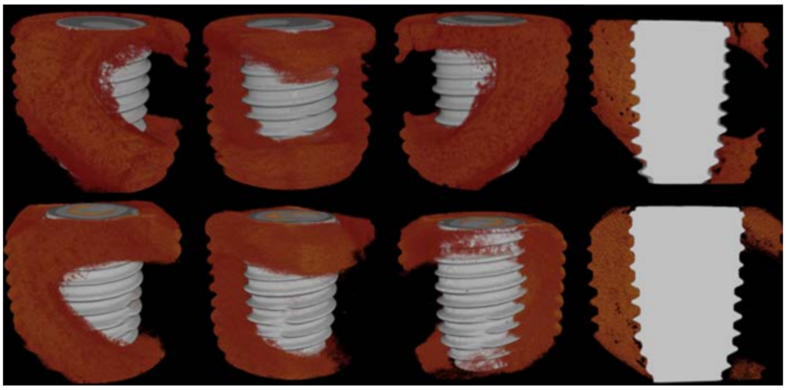

Figure 4: 3D Micro CT showing periimplant bone 12-weeks. Top: study group, bottom: control group

Table 1: Micro CT scan of bone parameters at 4 weeks.

4 weeks	Mean		SD		T value	P value
	Laser	Control	Laser	Control		
Bone to implant contact ratio	55.177	52.080	1.2067	1.033	5.51495	0.000076
Bone volume (mm3)	37.482	28.127	8.78508	2.0326	2.93443	0.010876
Intersection surface (mm2)	223.39	174.754	19.611	7.242	6.5803	0.000012
Bone surface density (1/mm)	7.759	7.486	0.185472	0.16702	2.98183	0.010603
Trabecular Thickness (mm)	0.27017	0.1805	0.0382	0.01288	6.28196	0.00002
Trabecular separation (mm)	0.8224	1.0165	0.0262	0.0543	-9.09002	0<00001
Trabecular number (1/mm)	1.8037	1.2451	0.11333	0.15816	8.11942	0<00001

Table 2: Micro CT scan of bone parameters at 8 weeks.

8 weeks	Mean		SD		T value	P value
	Laser	Control	Laser	Control		
Bone to implant contact ratio	59.418	56.377	0.91626	0.95396	6.08263	0.000028
Bone volume (mm3)	58.767	54	2.578	2.212	3.70851	0.002338
Intersection surface (mm2)	241.54	222.77	9.12218	4.41059	4.90146	0.000234
Bone surface density (1/mm)	11.480	10.088	1.05121	0.940822	2.61077	0.020542
Trabecular Thickness (mm)	0.2738	0.1779	0.0246	0.011830	9.28254	0<00001
Trabecular separation (mm)	0.68967	0.8857	0.01955	0.033637	-13.33094	0<00001
Trabecular number (1/mm)	2.639	1.6680	0.16892	0.21856	9.30036	0<00001

Table 3: Micro CT scan of bone parameters at 12 weeks.

12 weeks	Mean		SD		T value	P value
	Laser	Control	Laser	Control		
Bone to implant contact ratio	67.867	59.775	1.275	1.615	11.117	0<00001
Bone volume (mm3)	93.99	64.355	19.518	10.714	3.7655	0.0020
Intersection surface (mm2)	270.266	225.522	34.960	1.404	3.617	0.0028
Bone surface density (1/mm)	11.821	9.789	1.864	1.437	2.4406	0.0285
Trabecular Thickness (mm)	0.364	0.258	0.0304	0.0204	8.1354	0<00001
Trabecular separation (mm)	0.6369	0.760	0.0289	0.0340	-7.798	0<0001
Trabecular number (1/mm)	2.924	2.173	0.180	0.102	10.232	0<00001

According to Liu et al., LLLT, particularly in the early stages of bone healing, expedited fracture repair and enhanced callus volume[11]. LLLT was discovered to have favorable effects on the biostimulation of cells in in vivo comparative experiments using cell cultures[12]. According to the stages of bone fracture repair, LLLT may enhance resorption or formation activities[13]. Given the evidence of LLLT's beneficial effects on bone healing, osseointegration of implants can be accelerated or increased with LLLT. In their investigations using LLLT, Khandra et al. noted that the osseointegrations of titanium implants accelerated. The authors of this study stressed that LLLT helped osteopenic rats' implants to osseointegrate in a good way[14]. Recently, it was stated that LLLT output power for biostimulation shouldn't be greater than 1 W[15]. Studies have demonstrated that biostimulation increases at 0.3 W output power[16-18]. This information indicates that 0.3 W of output power is used in our investigation. The optimal wavelength for LLLT is said to be between 550 and 950 nm[19]. In our research, we used a diode laser with a wavelength of 940 nm. It was unable to define an effective dose for bone tissue, and the literature employed a wide range of doses[15]. The LLLT protocol that we applied in our study is similar to that of Khadara et al[14]. The tissue administered and the penetrating dose are two factors that affect how the laser affects the tissues. The term "energy" or "dose" refers to the amount of laser energy delivered per cm^2 of target tissue[15]. Although the dose was standardized for the tissues; no protocol could be established because the LLLT's effective wavelength on bone tissue was not[20]. Although different doses were employed in the literature, it was observed that an effective dose could not be determined on bone tissue. Similar studies in the literature demonstrate that bone tissue uses 3 to 10 J/cm2 of energy[7,12,21]. In this study, 6 J/cm2 energy was used.

In line with our study, Gomes et al.[22] have found that low level laser therapy improved bone formation and stability of dental implant. In an animal study, Naka and Yokose[23] have showed that laser promoted bone deposition around dental implants. The same conclusion was also reached by Martin et al.[24], who found that laser stimulated neoformation around mini-implants screws in ovariectomized rats.

However, other studies[25-27] have failed to demonstrate any beneficial effect of laser on stimulating periimplant bone. The variability in the laser irradiation technique, including the energy density and wave length, the duration of irradiation, and the difference in the quality and quantity of bone between animal models, is responsible for the diversity in the effect of laser on bone formation.

CONCLUSION

Photobiomodulation of periimplant bone enhances bone formation and facilitate the osseointegration of dental implants. The findings of this study may be extended for clinical application of laser to hasten osseointegration of dental implants placed in poor quality bones.

Authorship Contribution: Both authors share equal effort contribution towards (1) substantial contributions to conception and

design, acquisition, analysis and interpretation of data; (2) drafting the article and revising it critically for important intellectual content; and (3) final approval of the manuscript version to be published. Yes.

Potential Conflicts of Interest: None

Competing Interest: None

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