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The Reliability of Two Different Laser Wavelengths in Inducing Bone Healing Around Dental Implants: Comparative Clinical Trial

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Abstract

Background/purpose: Dental implantology involves different treatments that have been used in conjunction with dental implant surgery to increase implant stability and bone regeneration process. Photobiomodulation(PBM) can be one of these techniques. The objective of this study was to evaluate the bone density around implants. **Materials and methods:** in this study, 10 individuals had 20 implants inserted in the posterior of their mandibles. each patient received two implants the left side served as the control whereas the right side served as the study group with a diode laser (same patients). measurements were made for each implant. Measurements were obtained using cone-beam computed tomography (CBCT). **Results:** Cone beam computed tomography (CBCT)analysis found statistically significant quotient differences between the study groups were discovered. (P = <0.001) had a better degree of bone integration than the control group after 3 months of observation of different powers the best power effect on bone density around the implant from group 1 is 50 mW while the best power in bone density around the implant from group 2 is 4 W Conclusion: Effective osteogenesis promotion by photobiomodulation is possible; the bone healing process was accelerated around implants by different powers of 650nm and 976nm of the laser's photobiomodulation action.

Keywords: Dental implantology; biostimulation; diode lasers; PBM; bone density.

1. Introduction

A dental implant (also known as an end-osseous implant) has been used to substitute missing teeth for more than 50 years. Modern dentistry aims to get the patient back to normal function., contour, comfort, esthetics, speech, and health by replacing teeth with a prosthetic or treating a diseased tooth, a dental implant is a significant development in dentistry as has improved greatly the success rate of replacing lost teeth (Warreth et al,2017). Success in implant dentistry depends on several parameters that may improve the phenomenon of osseointegration and new bone formation in close contact with the implant (Jani et al,2015).

Implant stability is considered one of the most important factors affecting the healing and successful osseointegration of dental implants (Ibraheem et al,2015). The stability of an implant is its ability to sustain loads in axial, lateral, and rotational directions (Staedt et al,2020). Generally known to be "a measurement of the difficulty of moving an item or system from equilibrium (Atsumi et al,2007). Secondary stability results from osteointegration, a biological process, whereas primary stability is mechanical (Yoshiki Oshida et al,2007). By coincidence, the Swedish orthopedist Branemark and his associates discovered osseointegration the occurrence of bone integration with titanium in the 1960s. Consequently, osseointegration includes the clinically asymptomatic, hard fixation of alloplastic materials, which is maintained during functional loads (Duqum et al,2008).Osseointegration is defined as the direct structural and functional connection between both the titanium implant surface and the organized vital bone, which can receive functional loads (Albrektsson et al,1981). This connection is characterized by forming a thin layer of bone tissue around the implant, which becomes firmly attached to the implant over time without fibrous tissue in between (Abdullah et al,2023).

The clinical success of dental implants is directed by the implant surface and bone cell responses that promote rapid osseointegration and long-term stability (Turkyilmaz et al,2007). Implant stability is considered one of the most important factors affecting the healing and successful bone healing of dental implants (Heinemann F et al, 2o15). Many attempts have been made in recent years to enhance implant shape, design, materials, and processes to accelerate bone healing. process and implant density success rates. treatment with PBM is a new technology that has been developed to the osseointegration surrounding dental implants should be improved. Based on its capacity to stimulate the biochemical and molecular processes involved in tissue repair, increased to promote the biochemical and molecular mechanisms needed for tissue (Arakeeb et al,2019).

Laser light irradiation has been applied in the medical field and has biostimulatory effects on wound healing, collagen synthesis, and fibroblast proliferation in addition, laser light appears to increase mitochondrial respiration and adenosine triphosphate (ATP) synthesis (Avci P et al,2013). Furthermore, an adequate method of measuring the effectiveness of primary stability and bone density is required. Since the removal torque method and histomorphometry analysis measurements are invasive techniques (Matys et al,2015). Additionally, it has been noted that cone-beam computed tomography (CBCT) offers submillimeter isotropic voxels that enable precise measurements of bone density (error 0.1) (Matys et al,2019). The method can be considered a preferential diagnostic tool for bone, density evaluation during implant treatment as it provides qualitative and quantitative analysis (Matys et al,2015) (Dahiya et al,2018). Noninvasive osseointegration assessment technologies include X-ray imaging, cone beam computed tomography (CBCT), multislice computed tomography (CT), and micro-computed tomography (MCT) (Arakeeb et al 2019). Some studies have reported that PBMT has the best result when compared with other methods (Matys et al,2015) while other studies have reported no significant difference. This controversy may be due to multiple factors, some related to laser parameters and others related to the incorrect diagnosis of selected patients (García-Morales et al,2012). Any implant procedure's success is influenced by several patients- and procedure-related factors, including the patient's overall health the implant surface design, the biocompatibility of the implant material, the surgical procedure, and the quantity and quality of the surrounding bone (Parithimarkalaignan et al,2013).

The purpose of the study was to compare the effects of 650 and 976 nm diode lasers of varying powers on bone density around implants using computed tomography (CBCT). Using OnDemand software, relative bone density (RBD) was determined by placing a simulated implant at the inserted implant and adjusting it to the same size and position, then measuring the relative bone density using the software's verification tool.

2. Materials and method

The study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institute of Laser for post-graduate studies.

3. Design and Investigation of Nanowire Metasurface Grating Polarizer

Ten male patients (age: 30-50 years) with missing teeth for at least 6 months were randomly selected for this study. Each patient had received two implants (neoabietic company), On both sides of the lower jaw. According to the delayed implant placement protocol, the late insertion approach requires a 6- to 8-month waiting period between tooth extraction and implant placement (Gallucci GO et al 2018). Each group (divided into 2 groups Group 1(study group) 650nm (n=5, 10 implants), power used is 25 mW,50 mW, 75 mW,100 mW, and 200 mW on the right-side Time used 40 seconds, continuous emission mode and group 2 (study group) treated with 975nm (n=5,10 implants) power used is 0.5W,1W,1.5W,2W,4W on the right side. Time used 40 seconds, continuous emission mode. The left side of each group served as a control.

4. Diode Laser

The Woodpecker LX 16 diode laser used two wavelengths 650 nm and 976 nm, handpiece diameter:8mm, output differentness power, spot area: 0.5024 cm^2, continuous mode, time: 40 sec per point, 2 points (irradiation on a buccal and a lingual side of the alveolus/implant). when the irradiance law is used (irradiance = power/cm^2). Inclusion Criteria: Patients ranged in age from 30 to 50; they were missing lower posterior teeth; the working regions were edentulous for at least 6 months; and the investigation was performed on the lower jaw's two-sided structure. is shown in Fig.1.

Fig. 1. The patient's lower jaw two-sided missed lower posterior teeth.

The group1 and group2 (test) group's implants were irradiated with the aluminum gallium arsenide (diode laser) from Woodpecker Company according to the following protocol: immediately after the surgery and 3, 5, 7, 9,11,13,15,17, and 19 days. Exclusion Criteria Patients with significant bone loss, diseases that slow the healing process, such as diabetes and thyroid disease, females who could have hormonal changes that might alter the research's findings (Koszuta P et al 2015), and patients who get radiation or chemotherapy are all excluded from the study.

5. Surgical phase

All patients had surgery under local anesthetic made up of 2% lidocaine and 1:100,000 epinephrine, both provided by Novocol Pharmaceutical of Canada. Lower mandibular posterior left and right had a horizontal mid-crestal incision made using a #15 Bard-Parker blade through the connected gingival and rather lingual to the ridge's crest (3-4 mm to the crest), and the mucoperiosteal flap was bluntly dissected with a periosteal elevator and performed exposed buccally and lingually by a reflection on the alveolar ridge's buccal side.

Osteotomies were performed using a starting drill with a pilot hole of 2.0 mm, followed by further drills directed by the manufacturer at a drilling speed of (800 rpm), then the implant was put in its position shown in Fig.2. A Preoperative CBCT (Kavo OP 3D PRO, Biberach, Germany) was performed on the patients to assess bone density using the OnDemand3DTM software (Cybermed Inc., Seoul, Korea) (Mello-Machado et al., 2021). To examine the relative bone density around each implant, all patients in the two groups were tested by CBCT on the first day after implant insertion, followed by another one month later, and finally after three months. Relative bone density (RBD) was measured around the implants with OnDemand software by placing a simulated implant at the implanted implant and adjusting to the identical size and position, then measuring. The software's verification function was used to determine the relative bone density as shown in Fig.3.

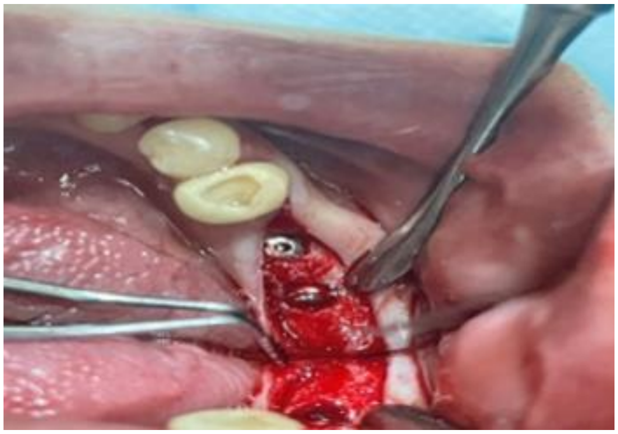

Fig. 2. Patient after implant placement.

Fig. 3. Using the verification tool in the simulation, measuring the relative bone density surrounding the simulated implants in On-Demand software.

Bone density (grayscale value) was measured at the two-sided around implant the implant of each patient. The greyscale value for all subjects was measured by CBCT software in recent years (CBCT) and has grown in acceptance in the dental field. Other studies discovered a strong correlation between the Hounsfield unit calculated from CBCT voxel values and real parameters of bone density acquired from Micro-CT and multi-slice CT, suggesting that CBCT may be used to measure bone density.

6. Statistical analysis

ANOVA analysis was performed. repeated measure compared to the control concentration. Information presented as mean SD. The letters (A, B, C, and D) are extremely significant beginning with the letter (A) or (a), decreasing with the final one. The least significant difference (LSD) test was used to assess the significant differences between the tested mean. Similar letters indicate that the tested means are not significantly different from one another. Values of $p>0.05$ were considered statistically unimportant while $p\leq0.05$ and $<0.01,0.001$ were considered extremely significant differences, significant differences respectively. The statistical analysis was carried out by SPSS (v 20).

7. Results

Measurement was taken for bone density around the implant in the Hounsfield unit for (HU) each implant between tested and controlled by On-Demand software immediately after implant placement, one month and 3rd month.

7.1 Bone density for the 650 nm group

The best result affected bone density around the implant in one day with a maximum mean value was 2112.96 HU. Following this, after one month of exposure to laser light at a wavelength of 650 nm, a power of 50 (mW) was found to have the best effect on bone density. This was supported by a maximum mean value of 1982.46 HU. When assessing the impact of laser wavelength on bone density over three months, the analysis indicated that a power level of 50 mW had the most significant effect on bone density around the implant area. This was evident through a mean value of 2134.52 HU. These findings are presented comprehensively in Table 1 and visualized through Figure 4, providing a clear representation of the influence of power levels and laser wavelength on bone density around implants.

Fig. 4. Comparison of power levels and their effects on bone density were analyzed across various study periods, focusing specifically on bone density around implants within Group 1.

Table 1: Comparison powers on bone density between the different studied periods according to bone density around implants of group 1.

Powers of 650 nm in watt	Bone density around implant in HU with 650 nM		Bone density around implant in HU with control		P VALUE
25	**mean**	**SD**	**Mean**	**SD**	
Time 1day/25	C 1297.18	376.10	1856.73	1188.94	0.001
Time 30 day/25	B 1866.36	826.58	1886.39	1247.12	NS
Time 90 day/25	**A 2049.67**	823.69	2015.71	1254.99	NS
P value	0.001		NS		
50	**mean**	**SD**	**Mean**	**SD**	**P VALUE**
Time 1day/50	**A 2112.96**	1311.34	B 1860.20	1259.48	0.001
Time 30 day/50	B 1982.46	1060.26	C 1638.83	956.65	0.001
Time 90 day/50	A 2134.52	1193.16	A 2007.37	1777.57	0.05
P value	0.001		0.001		
75	**mean**	**SD**	**Mean**	**SD**	**P VALUE**
Time 1day/75	C 1486.59	1106.23	A 1909.28	1349.39	0.001
Time 30 day/75	A 1768.11	918.38	C 1599.37	592.58	0.001
Time 90 day/75	B 1643.32	694.22	B 1719.56	586.41	0.05
P value	0.001		0.001		
100	**mean**	**SD**	**Mean**	**SD**	**P VALUE**
Time 1dy/100	C 1609.48	1451.46	1645.35	1400.74	NS
Time 30 day/100	B 1909.28	1349.39	1552.75	1277.01	0.001
Time 90 day/100	**A 2010.83**	1247.75	1683.27	1277.11	0.001
P value	0.001		NS		
150	**mean**	**SD**	**Mean**	**SD**	**P VALUE**
Time 1day/150	**C 1650.31**	990.09	1683.49	961.60	-
Time 30 day/150	**B 1768.41**	917.95	1751.48	875.43	-
Time 90 day/150	**A 1940.83**	934.06	1737.33	746.72	-
P value	0.001		NS		

Time: Time of measurement/ Day of implant placement.
*P value: calculated between the three times of measurement/LSD test was used to calculate the significant differences between tested mean, the letters (A, B, and C) represented the levels of significant, highly significant start from the letter (A) and decreasing with the last one. Similar letters mean there are no significant differences between the tested mean. $p \leq 0.05$ were considered significantly different.

7.2 Bone density for the 976 nm group

In one day, the maximum recorded power mean value is 2112.96 Hounsfield Units (HU) was achieved at a power of 1 watt. After one month, the most favorable power level for enhancing bone density in patients exposed to laser light at a wavelength of 976 nm was 4 watts. At this power level, the average mean value reached 2456.47 HU. The subsequent effective power level was 1 watt, resulting in an average bone density of 2346.23 HU. After three months, the impact of laser wavelength on bone density was examined. The most notable improvement in bone density around the implant site, with a maximum average of 2941.10 HU, was observed at a power level of 4 watts. Following closely was a power level of 1.5 watts, yielding an average bone density of 2636.50 HU. These findings are detailed in Table 2 and illustrated in Fig. 5.

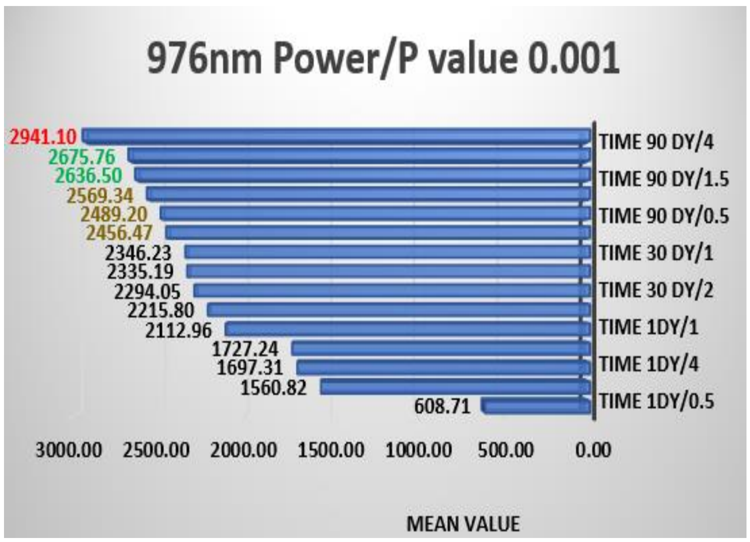

Fig. 5. Comparison powers on bone density between the different studied periods according to bone density around implants of group 2.

8. Discussion

Extrinsic bone healing stimuli, including those associated with the use of PBM, have been shown to improve implant osseointegration and have a positive impact on the healing and attachment of titanium implants (Blay et al,2016). Authors believe that the administered dose, or the proper energy density and power, determines the metabolic changes carried about by PBM that stimulate tissue regeneration as well as the proliferation and viability of reparatory cells (Fahimipour et al,2013). There is a lot of discussion around the research studies that have looked at how PBM alters the process of bone regeneration, which suggests that further studies are necessary to determine how PBM affects bone tissue (Fávaro-Pípi et al,2010). Our study aimed to determine the impact of the photo modulation on implant-bone density following peri-implant soft tissue irradiation with a 650 nm and 976nm diode laser accounted for significantly greater bone density after 3rd month in contrast to nonirradiated subjects. The main finding of the study was the best power of 4Win laser 976nm bone density around the implant after one month and 3rd month Because, in the infrared region, the absorption rate is small, so in order to obtain the best result, we increase power while in BDI the best power effect for the similar period the effect of 50 mW due to the absorption rate is higher in the visible region, so we did not need a higher power until we get bone density. The results of our study were in good agreement with (Matys et al,2019) found improved bone density, in the red to the near-infrared spectrum (600–1500nm), Thus, the energy can be absorbed by the soft tissue and bone.

Table 2: Comparison powers on bone density between the different studied periods according to bone density around implants of group 2

976 nm powers in watt	Bone density around implant in HU with 976 nm		Bone density around implant in HU control		P value
0.5	**mean**	**SD**	**Mean**	**SD**	
Time 1day/0.5	C 608.71	597.70	C 1083.26	160.71	0.001
Time 30 day/0.5	B 2215.80	402.05	B 1873.44	827.97	0.001
Time 90 day/0.5	**A 2489.20**	472.09	A 1936.09	806.62	0.001
P value	0.001		0.001		
1	**mean**	**SD**	**Mean**	**SD**	**P value**
Time 1day/1	C 2112.96	1311.34	C 1723.70	1452.52	0.001
Time 30 day/1	B 2346.23	691.10	B 2059.83	1552.04	0.001
Time 90 day/1	**A 2675.76**	812.27	A 2137.84	1521.12	0.001
P value	0.001		0.001		
1.5	**mean**	**SD**	**Mean**	**SD**	**P value**
Time 1day/1.5	C 1727.24	1102.44	C 1768.11	918.38	NS
Time 30 day/1.5	B 2335.19	507.12	B 1999.37	1158.26	0.001
Time 90 day/1.5	**A 2636.50**	372.65	A 2156.87	1225.07	0.001
P value	0.001		0.001		
2	**mean**	**SD**	**Mean**	**SD**	**P value**
Time 1day/2	C 1560.82	528.99	C 1965.48	1462.40	0.05
Time 30 day/2	B 2294.05	192.71	B 2061.51	1553.90	0.001
Time 90 day/2	**A 2569.34**	248.99	A 2138.68	1511.16	0.001
P value	0.001		0.001		
4	**mean**	**SD**	**Mean**	**SD**	**P value**
Time 1day/4	C 1697.31	1158.91	C 2007.00	1119.29	0.001
Time 30 day/4	B 2456.47	633.45	B 2138.37	1043.29	0.001
Time 90 day/4	**A 2941.10**	673.94	A 2260.88	1061.60	0.001
P value	0.001		0.001		

PBM also encourages nondifferentiated mesenchymal cells to differentiate into osteoblasts, which turn into osteocytes more quickly, and acts as an inducer factor that enhances vascularization has an anti-inflammatory impact, and enhances collagen synthesis, thus enhancing the bone healing process (Lopes et al,2005).The results from (Lopes et al,2005) support this study. Who concluded that PBM encourages improved bone regeneration around dental implants. On the other side, numerous studies have shown that PBM has no benefits and may even have negative consequences on osseointegration, (Pereira et al). This controversy may be attributed to many factors such as selected wavelength, high dose or very low dose, irradiation time, spot size, improper diagnosis, and the number of session treatments (Herranz-Aparicio J et al 2013). To overcome this problem a proper adjustment to power density is needed Within a specific relationship between dose and output power, PBM energy was discovered to have a favorable effect on bone regeneration.

9. Conclusion

Despite the limitations of this study, it can be concluded that photobiomodulation can significantly enhance bone healing around dental implants.

Author Contributions

All authors have contributed to the study's conception and design. The manuscript was written by [Zahraa A. Alameri]. Also, data collection and analysis were performed by [Zahraa A. Alameri]. Material preparation was performed by [Hussein A. Jawad]. All authors have read and approved the final manuscript before submission.

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موثوقية طولين مختلفين من موجات الليزر في تحفيز التئام العظام حول زراعة الأسنان: تجربة سريرية مقارنة

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الخلاصة

الخلفية / الغرض: تتضمن زراعة الأسنان علاجات مختلفة تم استخدامها جنبًا إلى جنب مع جراحة زراعة الأسنان لزيادة استقرار الغرسة وعملية تجديد العظام. يمكن أن يكون التعديل الضوئي (PBM) أحد هذه التقنيات. كان الهدف من هذه الدراسة هو تقييم كثافة العظام حول الغرسات.

المواد والطرق: في هذه الدراسة ، تم إدخال 20 غرسة في الجزء الخلفي من الفك السفلي لعشرة أفراد. تلقى كل مريض غرستين. الجانب الأيسر كان بمثابة التحكم بينما عمل الجانب الأيمن كمجموعة الدراسة باستخدام ليزر ديود (نفس المرضى). تم إجراء قياسات لكل غرسة. تم الحصول على القياسات باستخدام التصوير المقطعي المحوسب ذو الحزمة المخروطية (CBCT).

النتائج: وجد تحليل التصوير المقطعي بالحزمة المخروطية (CBCT) فروق ذات دلالة إحصائية في الحاصل بين مجموعات الدراسة. (P = <0.001) كان لديها درجة تكامل عظمي أفضل من المجموعة الضابطة بعد 3 أشهر من ملاحظة القوة المختلفة ، أفضل تأثير للطاقة على كثافة العظام حول الغرسة من المجموعة 1 هو. 50 ميغاواط في حين أن أفضل قوة في كثافة العظام حول الغرسة من المجموعة 2 هي 4 واط. **الخلاصة**: تعزيز تكوين العظم الفعال عن طريق التعديل الحيوي الضوئي ممكن ؛ تم تسريع عملية شفاء العظام حول الغرسات بواسطة قوى مختلفة من 650 نانومتر و 976 نانومتر من عمل التعديل الضوئي بالليزر.