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ORIGINAL PAPER

Effect of Light Emitting Diode Photobiomodulation on the Stability of Dental Implants in Bone Grafted Cases: a Split-Mouth Randomized Clinical Trial

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ABSTRACT

Introduction: *The high success rate of implants has made implant-based prostheses attractive to edentulous patients. Osseointegration lasts 4–6 months, increasing to 6–8 months in cases requiring bone grafts and guided bone regeneration. Many efforts have been made to accelerate osseointegration, including low level laser (LLL) and light emitting diode (LED) photobiomodulation.*

Materials and methods: *Twelve patients underwent bimaxillary immediate implant surgery with particulate bone grafts between the socket wall and the implant, and the transmucosal abutment was attached on implants at the same time. The intervention side was exposed to LED radiation for 20 minutes a day one day preoperatively and 10 consecutive sessions, starting from the day of surgery. A trained operator measured and recorded the implant stability quotient (ISQ) value on both sides immediately after surgery as well as one month and three months postoperatively.*

Results: *The ISQ value was 37.54 on the non-irradiated side immediately after surgery; it decreased to 35.09 one month postoperatively and increased to 46.45 at three months after the operation. The ISQ value was 36.73 on the irradiated side immediately after surgery and it increased to 47.36 and 71.18 at one month and three months postoperatively, respectively. There were significant differences between the ISQ values on the irradiated side at all the three time intervals, but also a significant difference on the non-irradiated side, except for two other two time intervals of immediately and one month after surgery. Although there was no significant difference between the two sides in terms of the ISQ value immediately after surgery,*

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the ISQ value was significantly higher on the irradiated versus non-irradiated side at one month and three months postoperatively.

Conclusion: *Low level laser radiation resulted in a favorable increase in the ISQ value in three months. Light emitting diode has lso led to a clinically significant increase in the ISQ value after three months because implants with ISQ values >54 could be loaded.*

Keywords: implants, implant stability quotient, LED, osseointegration, bone grafting.

INTRODUCTION

Tooth loss has always been a problem that human beings must face, and nowadays, with an increase in life expectancy, the age-related effect on tooth loss has also increased. Attempts to reconstruct missing teeth have been a fundamental need for all ages (1). However, most attempts were unsuccessful and unpredictable by the time when Brănemark introduced the endosseous dental implants (2). He discovered the close relationship between bone and titanium implants, with sufficient strength to transfer force, and called this phenomenon osseointegration (3, 4). The duration of osseointegration was considered to be 4–6 months in the early protocols, and implants were submerged and unloaded during the regeneration period (5). This time increases to 6–8 months in cases requiring bone grafts and guided bone regeneration (GBR) (6, 7), which is unacceptable for many patients; therefore, considerable efforts have been made to accelerate the completion of the osseointegration process, which are divided into two groups. The first group includes methods for improving implant properties such as implant biomaterials, implant design, surface topography and surface energy. The second group includes methods for enhancing the environment around the implant, including cytokines, growth factors, photobiomodulation using low level laser (LLL) and light emitting diode (LED) (8-12). Implant stability is another important issue affecting successful implant osseointegration. Implant stability is divided into two primary and secondary groups (13). The primary stability is achieved by mechanical engagement achieved by engaging the implant in bone during implant insertion. It depends primarily on bone quality and quantity, implant design and the surgical technique. With the start of postoperative osteoclastic activity, the bone-to-implant contact decreases (14, 15). The secondary implant stability is a biological event resulting from the activity of osteoblasts and bone resorption around the implant, which begins a few days after the placement of the implant. Both primary and secondary stability are essential for successful osseointegration. Primary stability decreases during the initial stages of regeneration and the secondary stability increases. Nevertheless, there is a critical period in the regeneration phase in which primary stability decreases faster than the pace at which secondary stability increases. If implants are not in an optimal condition at this time, treatment failure is possible, and this is of double importance, especially in implants undergoing immediate loading. The use of osteogenesis enhancement is helpful in these cases (13, 16). This critical period is estimated to begin 2–3 weeks after surgery in animal studies (16). Implant stability is measured in a variety of ways, the most invasive of which is the use of resonance frequency analysis (RFA) (17). The result is given as the ISQ value, which is between 1 and 100. A higher ISQ value represents a more stable implant. Various studies suggest the ISQ value of at least 54 for immediate loading (17-21). RFA measurement is more about frequent measurements of an implant over an exact time because it is very sensitive to changes in the implant–bone contact. *In vitro* and *in vivo* studies described the stimulatory effects of photobiomodulation around titanium implants (11, 12, 22-24), showing that photobiomodulation might not only promote wound healing, but also accelerate the osseointegration process, which would allow the possibility to load implants faster (25-27). Brawn *et al* reviewed implant stability after LED photobiomodulation and reported that implant stability increased in the LED-treated group, while LED photobiomodulation led to faster osseointegration of dental implants (10). Memarian *et al*

(2018) investigated the effects of LLL and LED on implant stability, which was measured in patients after 3, 4, and 8 weeks with periotest postoperatively; they concluded that LLL and LED had a positive effect on implant stability three weeks postoperatively (28).

Therefore, the aim of the present study was to evaluate the effect of LED photobiomodulation on implant stability in cases requiring bone grafts using resonance frequency analysis (RFA).

MATERIALS AND METHODS

The subjects of our study were selected from patients referring to the Implant Department of Tabriz Faculty of Dentistry, Iran, as well as private medical institutions based on inclusion criteria. All participants provided their informed consent before being involved in the study. The sample size (12 individuals) was determined according to the results of a previous study (29) and taking into account the mean ISQ value of 6.1±70.6 on the irradiated side and 5.7±79.6 on the non-irradiated side, with $\alpha=0.05$ and power=80%. Subjects were non-smokers and systemically healthy, with all requiring treatment of bilateral mandibular or maxillary implants with the same surgical conditions. They had healthy bone walls and no dehiscence or fenestration after tooth extraction, with a plaque index lower than 20%, bone type 3 or 4 in the surgical area.

Exclusion criteria consisted of pregnancy; presence of pathologic signs at the implant site; presence of systemic diseases such as uncontrolled diabetes, cardiovascular diseases and autoimmune diseases interfering with regeneration of soft and hard tissues; patients for whom it was not possible to place implants in one stage and there was a need for submersion; and use of steroids, immunosuppressants and bisphosphonates.

In patients who needed immediate maxillary or mandibular implant surgery in both quadrants and similar dental areas (premolars or firs molars), the teeth underwent atraumatic extraction, so that the socket wall remained intact. Implants of similar length and width (Dio Implant, Busan, South Korea) were then placed in the same dental areas in the opposite quadrants, and the area between the socket wall and the implant was grafted using bone powder at the same time (Bio Base, Bio Vision, Germany). Transmucosal abutments were then attached to implants and suturing was carried out to close the flaps together. Patients who had sockets with dehiscence after tooth extraction or those with no primary stability for transmucosal abutment connection during the implant insertion were excluded.

All surgeries were performed by a single clinician. Since this was a split-mouth study, one side of each patient was selected for radiation according to the OsseoPulse protocol (MEGAGEN, Seoul, South Korea), and exposed to the LED the first day before surgery and for 10 consecutive sessions starting from the day of surgery for

FIGURE 1. MEGA ISQ device

FIGURE 2. BIOLUX device

FIGURE 3. Patient irradiating a LED

FIGURE 4. Insertion the Smartpeg and measuring ISQ

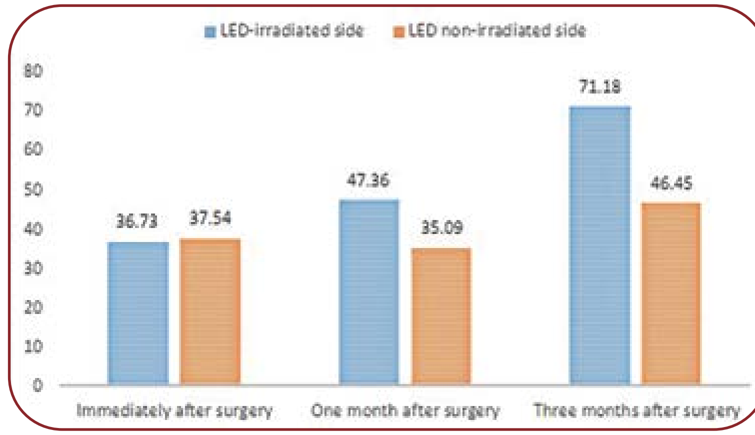

FIGURE 5. The ISQ value immediately after surgery and one month and three months postoperatively on both the irradiated and non-irradiated sides

20 minutes daily. The trained person who was not aware of the study methodology measured the ISQ value using Mega ISQ on both sides immediately after surgery as well as one month and three months postoperatively, and recorded in a table for the same person (Figures 1-4). The ethical committee registered the present study under the following number: IR.TBZMED.REC.1397.910.

Statistical analysis

Data were analyzed using descriptive statistics (mean±SD). Paired t-test was used to compare the ISQ values on the irradiated and non-irradiated sides. In case of normal distribution of data, paired t-test and non-parametric equation (Wilcoxon test) were used. Statistical analysis was performed using SPSS 17 at a significance level of $P<0.05$. Kolmogorov-Smirnov test showed an abnormal distribution for the ISQ value on the non-irradiated side one month after surgery and normal distribution for other variables. Therefore, a non-parametric test such as Wilcoxon test was used to compare the ISQ values on the irradiated and non-irradiated sides one month postoperatively; t-test was also used to investigate other research objectives.

RESULTS

Subjects included five men and six women, with a mean age of 44.75 years (range 35–75 years). The ISQ value immediately after surgery was 37.54 on the non-irradiated side, which decreased to 35.09 one month after surgery; however, it increased to 46.45 three months postoperatively. Kruskal-Wallis ($P=0.001$) and Wilcoxon tests showed no significant difference in the ISQ value immediately after surgery and and one month postoperatively ($P<0.05$); however, a significant difference was observed three months after surgery versus one month postoperatively and immediately after surgery ($P<0.05$). On the irradiated side, the ISQ value was 36.73 immediately after surgery, which increased to 47.36 and 71.18 one month and three months postoperatively, respectively (Figure 5). ANOVA ($P=0.00$) and post hoc Tukey tests revealed significant differences in the ISQ values between the three time intervals ($P<0.05$). The results showed no significant difference in the ISQ values immediately after surgery on both the irradiated and non-irradiated sides ($P=0.785$). The ISQ value was significantly higher on the irradiated side compared to the non-irradiated side one month after surgery ($P=0.04$). In addition, the ISQ value significantly increased in the irradiated side three months postoperatively ($P=0.001$).

DISCUSSION

The success of implant therapy depends on adequate bone volume at the insertion site (30). Otherwise, long-term implant prognosis is compromised. Considering the increased demand for implant therapy, different materials and techniques have been proposed to increase the width and height of the residual ridge, which include the methods of distraction osteogenesis, grafting, bone splitting, and GBR (31, 32). The duration of osseointegration in cases requiring bone grafts is sometimes over eight months, and this time is not acceptable for patients. Therefore, efforts have been made to accelerate the time of osseointegration, using techniques that are divided into two groups. The first group includes methods for improving implant properties such as implant biomaterials, implant design, surface topography and surface energy; the second group consists of methods for enhancing the area around the implant, including inclusion of cytokines, growth factors, and LLL and LED photobiomodulation (8-12).

Considering the increased demand for implant-based prosthetic therapies and the extensive use of implants in dentistry, and in particular immediate implant surgery, and the use of bone grafts in implant surgery, the present study investigated the effect of LED photobiomodulation on the stability of immediate implants that are used along with bone grafts. To reduce the effects of confounding factors on the samples, including gender, age, jaw, and quality and quantity of available bone, our study was designed as split-mouth, and similar dental areas and implants with similar diameter and length were used in the case and control areas. All surgical procedures were performed by a single operator in order to eliminate inter-operator variability, and the same bone graft material was used in all patients. Statistical analyses showed that the ISQ values on the non-irradiated and irradiated sides were 37.54 and 36.73 immediately after surgery, respectively, with no statistically significant difference. Therefore, the primary preoperative LED radiation had no effect on the primary stability immediately after surgery. In a study on the therapeutic effect of LLL on titanium dental implant, Kim *et al* found an increased expression of osteoprotegerin (OPG) and RANKL in the bone tissue during the osseointegration process. They then concluded that LLL affected the expression of OPG and RANKL, and thus increased the metabolic activity of the bone and the activity of osseous cells (11). Their findings showed no difference between control and intervention groups on the first day.

Statistical analysis of the RFA measurement one month after surgery showed that the ISQ value decreased to 35.09 on the non-irradiated side; however, it increased to 47.36 on the irradiated side, indicating that the amount of bone resorption around the implant was higher on the irradiated side compared to the non-irradiated side, probably leading to higher odds of successful osseointegration. However, the differences were not statistically significant. Various studies have shown a decrease in the stability rate on the third and fourth weeks postoperatively (31, 32); such decrease has not been seen in the radiation group, which might be attributed to the effect of LED photobiomodulation on the osseointegration process. In a study on implant stability after LED photobiomodulation, Brawn *et al* concluded that implant stability was higher in the LED-treated group and LED photobiomodulation improved implant stability (10).

Memaria *et al* investigated the effect of LLL and LED on implant stability. They measured implant stability 3, 4 and 8 weeks postoperatively using the periotest technique and found that both LLL and LED had a positive effect on implant stability three weeks postoperatively (28). The results of the present study have also shown that LED improved implant stability one month postoperatively, which was consistent with Memaria's report. Although LED radiation was carried out for 21 days in Brawn's study and for only 10 days in the present study, similar results were achieved in both studies. However, this finding might be used to immediately load implants that require immediate loading (esthetic zone). According to RFA statistical analysis, the ISQ value increased on both the irradiated (46.45) and non-irradiated sides (71.18) three months after surgery. The ISQ value has significantly increased on the irradiated side three months postoperatively, with statistical analyses confirming that these changes were significant. Therefore, it can be pointed out that LED radiation led to an increased ISQ value three months postoperatively, indicating a higher success rate for osseointegration. The elevated ISQ value can be clinically significant, given that previous studies found ISQ values >54 to be sufficient for implant loading (31, 32).

In a study on the effect of LED on implant osseointegration, Gokmenoglu *et al* (2014) showed that the use of LED in surgical areas was beneficial for the osseointegration process, leading to implant stability (33), which was consistent with the results of the present study. Morales *et al* investigated the post-LLLT implant stability in eight patients at 3, 6, 9, 10 and 12 weeks after surgery and found that the highest ISQ value was obtained at 10 days postoperatively; the ISQ value decreased until the sixth week and then increased (34). However, the present study indicated that the ISQ value increased over time and did not decrease at all. The discrepancy between the results might be attributed to the duration of radiation, because irradiation was given every 48 hours up to the 14th day after the intervention in Morales' study but on a daily basis and only until the tenth day postoepratively in the present study.

CONCLUSION

Based on the results of statistical analyses that were performed in the current research, the ISQ value was not modified by LED intervention immediately after surgery and it slightly increased one month postoperatively. Also, LED irradiation led to a favorable increase in the ISQ value three months after surgery, which was a clinically significant increase, given that implants with ISQ values >54 could be loaded. ❑

Conflicts of interest: none declared.

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