RESEARCH PAPER

Comparative Evaluation of Dental Implant Stability and Peri-Implant Soft Tissue Healing with and without Photobiomodulation Therapy

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Background: Photobiomodulation therapy (PBMT) has been proposed as an adjunctive treatment to enhance tissue repair and osseointegration following dental implant placement. However, its effect on implant stability and peri-implant soft tissue healing remains inconclusive.

Objective: To comparatively evaluate the effect of PBMT on dental implant stability and early peri-implant soft tissue healing following implant placement.

Materials and Methods: This comparative clinical study included 20 patients requiring dental implants, who were allocated into two groups of 10 each. The PBMT group received photobiomodulation therapy following implant placement, whereas the control group underwent conventional implant placement without PBMT. Implant stability was assessed using resonance frequency analysis and expressed as Implant Stability Quotient (ISQ) values immediately after implant placement and during second-stage surgery. Peri-implant soft tissue healing was clinically evaluated one week postoperatively. Data were analyzed using appropriate statistical tests, and $P < 0.05$ was considered statistically significant.

Results: The mean primary stability was higher in the PBMT group (72.90 ± 3.843) than in the control group (69.80 ± 3.490), although the difference was not statistically significant ($P = 0.075$). Similarly, secondary stability was higher in the PBMT group (69.20 ± 3.967) compared with the control group (64.90 ± 7.593), without statistical significance ($P = 0.130$). Peri-implant soft tissue healing was significantly better in the PBMT group ($P = 0.030$).

Conclusion: PBMT significantly improved early peri-implant soft tissue healing but did not significantly influence implant stability. It may serve as a promising adjunctive modality for enhancing early postoperative healing following dental implant placement.

Keywords: Dental implants; Implant stability; Implant Stability Quotient; Photobiomodulation therapy; Peri-implant healing; Resonance frequency analysis.

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INTRODUCTION

Dental implants are a well-established treatment method for partially and fully edentulous individuals. The achievement of a successful implant therapy depends on the realization of a stable bone-implant interface through osseointegration and the formation of healthy peri-implant soft tissues. Therefore, implant stability and peri-implant tissue healing are critical indicators to assess the biological response after implant implantation.[1]

Implant stability is often referred to both primary and secondary stability. Primary stability refers to the mechanical stability attained at the time of implant placement and is determined by bone quality and quantity, implant design, implant size,

surface features and surgical technique. Secondary stability arises throughout the healing phase because of bone growth, remodeling, and biological integration at the bone-implant contact.[1,2] A key factor in successful osseointegration is the transition from primary mechanical stability to secondary biological stability.

RFA (resonance frequency analysis) is a non-invasive approach commonly used to quantitatively test implant stability. It gives an Implant Stability Quotient (ISQ) value which can be recorded at various phases of implant healing. ISQ measures are important to monitor changes of implant stability over time but they can be impacted by various factors, particularly local bone quality, implant size, implant position and clinical circumstances.[2,3] Therefore, serial examination of ISQ may offer useful information on changes in implant stability during osseointegration.

Peri-implant tissues undergo a well-orchestrated healing process of inflammation, cell proliferation, angiogenesis, extracellular matrix production, epithelialization, and tissue remodeling following implant insertion. Early soft tissue recovery is of special importance, as the peri-implant mucosa is involved in the creation of a biological barrier around the implant, and shields the underlying tissues from the oral environment.[4] Therefore, therapies that modulate inflammation and promote cellular repair may have potential clinical relevance in the early postoperative period.

Photobiomodulation therapy (PBMT), originally known as low-level laser therapy (LLLT), has received growing attention as an additional treatment in implant dentistry. PBMT is the application of red or near-infrared light of low intensity to biological tissues. The processes postulated include control of mitochondrial function, cellular metabolism, inflammatory response, angiogenesis and tissue healing.[5] These biological consequences warrant further investigation of PBMT as an adjuvant to standard implant surgery.

The clinical evidence for the effect of PBMT on implant durability is promising but variable. Chen et al. in a systematic review and meta-analysis reported that PBMT might have benefits on implant stability and implant success, however the studies included had quite a variation.[6] In a recent systematic review and meta-analysis by Li et al., 20 clinical studies were assessed and PBMT was found to considerably increase implant stability at roughly 10 days after implant implantation. However significant changes were not consistently seen at later time points.[7] These results suggest that PBMT might influence early implant healing, although the effect on implant stability may depend on treatment regimen and time of assessment.

The effect of PBMT on ISQ readings has been studied further in clinical trials . Bozkaya et al. investigated PBMT following one-stage implant insertion and evaluated primary and secondary stability with RFA.[8] Similarly, Camolesi et al. performed a randomized double-blind clinical trial using combined 630 and 808 nm diode laser PBMT. There was no statistically significant difference in mean implant stability across groups over time, however the PBMT group had more favorable postoperative healing with less inflammation.[9]

More recently, Shenoy et al. in a randomized clinical trial, examined the effects of LLLT on ISQ levels at different postoperative intervals. The authors observed that the laser-treated group had higher ISQ values with significant differences at specified follow-up intervals, suggesting that PBMT may have a positive effect on implant stability and osseointegration.[10] Nevertheless, these results should be considered with caution, since the laser wavelength, energy density, irradiation time, treatment repetition, implant features, and patient-related factors can affect the results of the treatment.

While there is growing evidence for PBMT, few clinical studies have investigated both implant stability and early soft tissue healing at the same time. Evaluation of these outcomes may provide a better understanding whether PBMT has measurable benefits in the early healing phase after implant placement.

Therefore, the present study aimed to comparatively assess the stability of dental implants and healing of the peri-implant soft tissues after implant implantation with and without additional photobiomodulation therapy. Resonance frequency analysis was used to measure implant stability at primary and secondary phases, and a standardized clinical healing assessment was used to measure early peri-implant soft tissue healing.

METHODOLOGY

A comparative clinical study was performed to assess the impact of adjunctive photo-biomodulation treatment (PBMT) on dental implant stability and peri-implant soft tissue healing after implant implantation. The study population included individuals who were scheduled to get dental implants in the posterior jaw and who fulfilled the pre-determined inclusion criteria. The sample size was estimated using G*Power software v.3.1.9.2 with an effect size of 0.30 and alpha error of 0.05 and statistical power of 95%. The total sample size computed was 20 observations with 10 observations given to each of the study groups.

Inclusion criteria were patients in the age group of 18–65 years with partial edentulous posterior mandible and enough alveolar bone volume for implant implantation without the necessity of bone grafting. Participants were required to have no systemic illnesses known to adversely influence bone or soft tissue healing and provide willingness to participate, and cooperate with the scheduled follow-up. Exclusion criteria included a history of smoking, systemic disorders affecting bone or soft tissue healing, drugs altering bone metabolism, poor oral hygiene, active periodontal disease, or any local contraindication for regular implant placement.

Participants were randomly assigned into two groups of 10. Group A (PBMT group) received implant implantation and concomitant photobiomodulation therapy, Group B (control group) was given implant placement without PBMT. Both groups were placed with implants using a uniform methodology. Two-stage surgical implant protocol was followed. Implants were implanted at the crestal bone level and allowed to recover in immersed form. Primary implant stability was evaluated by resonance frequency analysis (RFA) immediately after the implant placement, and the related Implant Stability Quotient (ISQ) values were recorded.

In the PBMT group, photobiomodulation therapy was applied after implant placement according to the research protocol. The laser was used in four directions around the implant site during the implant surgery. The control group was subjected to the identical surgical implant procedure without laser irradiation.

Implant stability was assessed utilizing resonance frequency analysis at two assessment sites. Primary implant stability was examined immediately after implant placement and secondary implant stability was evaluated at the moment of implant exposure at the second-stage operation. RFA measurements were expressed as ISQ values. Finally, primary and secondary ISQ values were compared between PBMT and control groups to evaluate the effect of supplemental photobiomodulation on implant stability during the healing period.

Clinical evaluation of peri-implant soft tissue healing was carried out one week after implant placement utilizing a standardized healing index. The healing response was graded as very poor, poor, good, very good, or excellent. Standardized intraoral images were also taken at the designated evaluation period to record the clinical appearance of the peri-implant soft tissues and to compare the healing trends between the two groups.

Primary outcome measurements were primary and secondary implant stability as ISQ values and secondary outcome measure was peri-implant soft tissue healing by standardized clinical healing index. The independent t-test was used to compare the continuous variables (primary and secondary ISQ values) between the PBMT and control groups. Categorical soft tissue healing results were compared using the chi-square test. Fisher's exact probability was employed when suitable due to the small sample size. Values of $P < 0.05$ were deemed as statistically significant.

RESULTS

We evaluated 20 observations, 10 observations in the photobiomodulation therapy (PBMT) group and 10 observations in the control group. Implant stability was measured using Implant Stability Resonance frequency analysis and expressed as Implant Stability Quotient (ISQ) values at the primary and secondary evaluation time points. The peri-implant soft tissue healing was clinically evaluated 1 week after implant placement.

Mean primary implant stability was 72.90 ± 3.843 ISQ in PBMT group, and 69.80 ± 3.490 ISQ in control group. The mean primary stability was higher in the PBMT group, however, the between group difference was not statistically significant ($t = 1.889$, $P = 0.075$).

The PBMT group had a mean secondary implant stability of 69.20 ± 3.967 ISQ and the control group had a mean secondary implant stability of 64.90 ± 7.593 ISQ. Again, the PBMT group had a higher mean value of stability but the difference was not statistically significant ($t = 1.587$, $P = 0.130$). Therefore, primary and secondary implant stability values were numerically higher in the PBMT group, but the difference was not statistically significant for either.

Statistical analysis revealed a significant difference in peri-implant soft tissue healing between both groups. In the PBMT group, 6 observations (60%) were very good healing and 4 (40%) were excellent healing, with no observations being good healing. The control group however showed a good healing in 4 observations (40%) and very good healing in 6 observations (60%) and no observation had excellent healing. There were significant differences in soft tissue healing between the groups ($P=0.030$).

Table 1. Comparison of primary and secondary implant stability between the PBMT and control groups

Parameter	**Group**	**N**	**Mean ISQ**	**SD**	***t* value**	***P* value**
Primary stability	PBMT	10	72.90	3.843	1.889	0.075
	Control	10	69.80	3.490		
Secondary stability	PBMT	10	69.20	3.967	1.587	0.130
	Control	10	64.90	7.593		

Table 2. Comparison of peri-implant soft tissue healing between the PBMT and control groups

Group	**Good, n (%)**	**Very Good, n (%)**	**Excellent, n (%)**	**χ^2 value**	***P* value**
PBMT	0 (0.0)	6 (60.0)	4 (40.0)	8.000	0.030*
Control	4 (40.0)	6 (60.0)	0 (0.0)		

DISCUSSION

The aim of the present comparative clinical study was to evaluate the effect of adjunctive photobiomodulation therapy (PBMT) on the stability of dental implants and early healing of the peri-implant soft tissue. The results showed a tendency for higher mean primary and secondary implant stability values in the PBMT group than in the control group which was not statistically significant. In contrast, the healing of soft tissue around the implant showed a statistically significant difference. The PBMT group showed better healing results. The results indicate that the clinical benefit of PBMT in the present study was more evident in early soft tissue healing than in implant stability measured by resonance frequency analysis (RFA).

Implant stability is a critical clinical parameter in the transition from mechanical stability immediately after placement to biological stability during osseointegration. The lack of statistically significant difference in implant stability is consistent with several clinical studies. Kinalski et al. evaluated the low-level laser therapy in implants placed in healed sites and found that laser therapy did not significantly improve implant stability during the healing period.[13] Both groups showed an increase in implant stability over time, but the difference in ISQ between laser-treated and control implants was not significant. These results suggest that the natural course of osseointegration might be more important than PBMT alone to implant stability.

Similarly, Lobato et al . evaluated the effect of low-level laser therapy on the stability of implants placed in fresh extraction sockets.[14] Their randomized clinical trial showed no significant difference in implant stability between laser-treated and control implants. The difference between fresh extraction sockets and healed sites may affect the response to PBMT, as the biological environment and healing dynamics are completely different between these clinical situations.

In a randomized clinical trial, Kuzu et al. investigated the impact of photobiomodulation on implant stability and peri-implant bone response.[15] The authors reported that despite the positive biological effects, PBMT did not consistently improve implant stability. These observations lend support to the hypothesis that PBMT may affect cellular and tissue-level healing without necessarily

causing a significant measurable change in mechanical implant stability.

Some studies reported beneficial effects of PBMT on implant stability at specific post-operative time points.[16,17] A clinical trial of low-level laser therapy surrounding dental implants showed significant differences in ISQ values at selected follow-up periods suggesting that PBMT may influence the biological phase of implant healing.[10] Such differences between studies may be associated with differences in wavelength, energy density, irradiation time, treatment frequency, implant characteristics, quality of bone and timing of stability determination.

The most significant finding in the present study was the statistically significant difference in peri-implant soft tissue healing. This is supported by clinical evidence that PBMT has positive effects on soft tissue healing after surgery. A 2021 double-blind randomized clinical trial evaluated PBMT after dental implant surgery, and reported benefits in soft tissue wound healing.[18] The investigators applied red and near-infrared diode laser irradiation immediately after surgery and found better postoperative healing in the laser group. These results agree with the findings of the present study and suggest that PBMT may have a clinically significant effect on early tissue repair.

The results are also similar to those reported by Camolesi et al., who evaluated PBMT in a randomized double-blind clinical study with 40 dental implants.[9] Although the mean implant stability was not significantly different between the groups, the PBMT group had significantly better results for the healing index. Nine implants in the PBMT group achieved the maximum healing index whereas two implants in the control group. The authors also found less postoperative inflammation after PBMT. This pattern is quite similar to the present study, in which the effect of PBMT was more obvious on soft tissue healing than on implant stability.

The positive effect of PBMT on early wound healing could be attributed to its hypothesized action on cellular metabolism, inflammation, angiogenesis, and tissue repair. PBMT can promote fibroblast proliferation, collagen synthesis, vascular responses, and tissue remodeling via stimulation of mitochondrial activity and cellular signaling.[19,20] These biological effects may be especially relevant in the early postoperative period, when wound healing is dominated by inflammatory and proliferative processes.

Clinical studies also suggest that PBMT may help lower inflammatory responses after surgery.[21,22] In the randomized clinical study by Camolesi et al.[9], the application of PBMT was significantly related to the likelihood of postoperative inflammation. Such anti-inflammatory effects could be responsible for the improved clinical healing seen in the PBMT group in the present study.

However, the literature on PBMT and implant stability remains inconsistent. Li et al (2019) conducted a systematic review and meta-analysis of 20 clinical studies and found that PBMT increased implant stability significantly around 10 days after implant placement, but the significant benefits were not consistently observed at later time points.[8] The authors also found little evidence of improvement in other postoperative outcomes. This temporal variation may account for why PBMT does not consistently show significant effects across different studies. However, the significant improvement in soft tissue healing supports the potential of PBMT as an adjunctive approach in the early postoperative phase. Further, well-powered randomized clinical trials are required, employing standardized laser settings, serial ISQ readings, objective soft tissue evaluations, and extended follow-up, to determine the long-term clinical significance of PBMT in implant therapy.

CONCLUSION

Photobiomodulation therapy significantly improved early peri-implant soft tissue healing following dental implant placement. Although primary and secondary implant stability were numerically higher in the PBMT group, the differences were not statistically significant. PBMT may therefore be considered a promising adjunctive modality for enhancing early postoperative soft tissue healing.

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