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INFLUENCE OF CHITOSAN-BASED BIOCOMPOSITE COATINGS ON MARGINAL BONE RESORPTION AROUND MODIFIED IMPLANT ABUTMENTS ONE YEAR AFTER FUNCTIONAL LOADING

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ABSTRACT Osseointegration is a fundamental prerequisite for the long-term success of dental implants, relying on a stable interface between the implant surface and surrounding bone. However, microleakage at the implant–abutment interface facilitates bacterial penetration and the accumulation of endotoxins, which may induce a persistent inflammatory response and contribute to marginal bone resorption and peri-implant disease. In this context, contemporary bio-tissue engineering strategies aim to modify implant components in order to enhance biological sealing and reduce microbial colonization. The present study focuses on the application of modified implant abutments coated with a bio-composite material based on 2% chitosan. Owing to its well-documented antibacterial properties, chitosan has the potential to inhibit biofilm formation and reduce bacterial load in the peri-implant environment. This indirect antimicrobial effect may contribute to the prevention of peri-implant inflammation and, consequently, to the preservation of marginal bone levels. The investigation evaluates the influence of these modified abutments on microbial colonization and their potential role in limiting marginal bone resorption over time. By targeting the implant–abutment interface, the proposed approach seeks to reduce microleakage-related contamination and improve the biological stability of peri-implant tissues. The findings support the concept that chitosan-based bio-composite coatings represent a promising strategy in implant dentistry, combining antimicrobial activity with favorable biocompatibility. Such modifications may enhance peri-implant tissue integration, reduce the risk of peri-implantitis, and contribute to maintaining stable bone conditions, ultimately improving the long-term prognosis of dental implants.

KEYWORDS : chitosan, dental implants, marginal bone loss

INTRODUCTION

Osseointegration is defined as a continuous structural, functional, and symbiotic relationship between living, appropriately remodeled biological tissues and synthetic implant components with specific clinical functions, which are accepted by the host without eliciting a rejection response (1). An implant is considered osseointegrated when no progressive changes occur at the interface between the implant and the surrounding bone in direct contact (bone-to-implant contact, BIC) (2). In most two-piece implant systems, the size of the microgap at the implant–abutment interface (IAI) ranges from 0.1 µm to 10 µm after connection and prior to loading, and may further increase under cyclic loading (3,4). Accordingly, the implant–abutment interface (IAI) may serve as a conduit through which bacteria and endotoxins infiltrate the internal cavity of the implant, facilitating a bidirectional interchange between the implant interior and the surrounding peri-implant oral milieu (4,5). The movement of bacteria, their toxic derivatives, and small molecular entities across the IAI is referred to as microleakage. Accumulating evidence suggests that neutrophil infiltration in the vicinity of the implant–abutment interface (IAI) increases with greater implant depth, whereas the highest density of neutrophils remains consistently confined to the interface region irrespective of implant positioning (6). These findings imply that microleakage may trigger a sustained inflammatory reaction, which in turn can promote alveolar bone loss and contribute to the onset of peri-implantitis (7-12). The extent of microleakage is also dependent on the design of the implant–abutment connection. Morse taper configurations typically exhibit reduced leakage compared with butt-joint connections under both static and dynamic loading conditions (13). Interface stability is further influenced by the taper angle, geometric design, and extent of the contact surface. Moreover, insertion torque plays a significant role, with elevated torque values being associated with diminished bacterial penetration. The internal space of the implant has been identified as a potential reservoir for microbial colonization. Following abutment disconnection or replacement, microorganisms may gain access to and persist within this compartment, where they are able to survive and multiply (14). Consequently, microbial contamination may arise from both the peri-implant environment and the internal implant cavity (15). This enclosed space is readily accessible to bacteria yet challenging to adequately decontaminate, thereby permitting continuous accumulation of microbial populations and their associated toxic metabolites. Endotoxins, particularly lipopolysaccharides originating from Gram-negative bacteria, are recognized as key mediators in marginal bone resorption. Owing to their small molecular size, endotoxins are capable of diffusing through microgaps that are impermeable to whole bacterial cells and, once released from the implant interior, may stimulate osteoclastic activity leading to bone resorption (16). This mechanism has also been linked to systemic immunoinflammatory responses. Tissue engineering remains a key advancement as well as a continuing challenge in modern medicine. Although peri-implant diseases are well documented, prevention is still the most effective strategy, and biocomposite materials may offer a promising preventive approach. In the present study, which investigates the effect of modified abutments on marginal bone resorption, particular attention is given to the biological mechanisms governing the interaction between implant surface characteristics and peri-implant tissues (17,18). Previous studies have shown that fibroblast and epithelial cell responses are strongly influenced by surface chemistry and microtopography. A stable soft tissue seal is essential for limiting bacterial colonization and subsequent inflammatory processes that contribute to marginal bone loss. In this context, the use of 2% chitosan-modified abutments is proposed as a strategy to enhance soft tissue integration, promote favorable connective tissue organization, and reduce apical soft tissue migration, thereby potentially minimizing peri-implant bone resorption.

CASE STUDY

The present study included a total of 40 patients, divided into two independent groups of 20 individuals each, all of whom underwent dental implant treatment with the placement of a single dental implant per patient. The test group comprised patients treated with implants restored using abutments coated with a bio-composite based on 2% chitosan, whereas the control group included patients treated with implants and abutments without any biological coating. The main outcome measure was marginal peri-implant bone loss, assessed in millimeters using digital periapical radiographs of the placed implants. Dental implants were placed following a conventional two-stage surgical protocol. After an initial healing period of three months, a second-stage procedure was performed, including flap elevation under local anesthesia and removal of the cover screw, followed by placement of a healing abutment selected according to soft tissue conditions and prosthetic requirements. After a two-week soft tissue maturation period, the healing abutment was removed and an intraoral scan was performed using a Trios 3Shape scanner (3Shape, USA). Digital impressions were exported in STL format for CAD/CAM processing. A screw-retained temporary crown was digitally designed and fabricated using SLA 3D printing (Formlabs Form 2, Formlabs, USA) with PMMA Temporary CB Resin, and extraorally cemented to the prosthetic base using self-adhesive resin cement (Breeze™, Pentron). In the definitive prosthetic phase, the final restoration was placed on a titanium base, and the screw access channel was sealed

with Teflon tape and composite resin (Breeze™, Pentron). In the control group, standard uncoated abutments were used, whereas in the test group, abutments were modified with a bioactive coating consisting of 2% chitosan only. The coating was applied using a film deposition technique under aseptic conditions in a laminar flow cabinet. The chitosan solution was prepared by dissolving 2 g of chitosan in 2% acetic acid under magnetic stirring at 200 rpm for 30 minutes. For comparative analysis, radiographic examinations were performed immediately after implant placement and one year following functional loading of the dental implants. The marginal bone level was assessed in order to evaluate the potential influence of the modified abutments on peri-implant bone response over time.

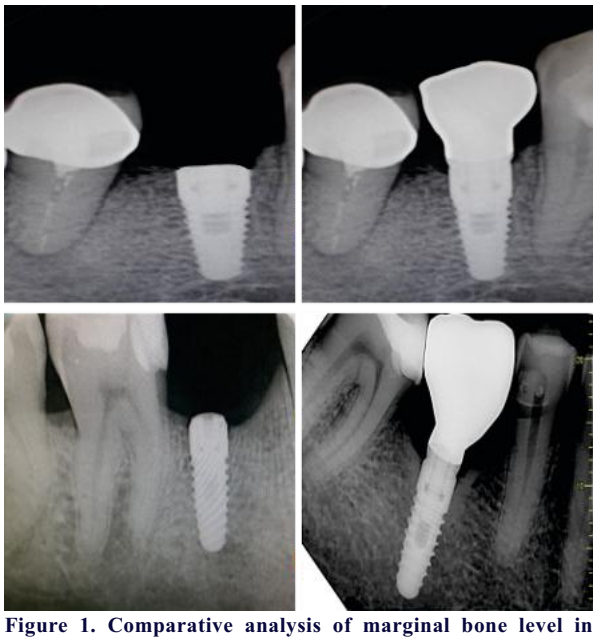

Figure 1. Comparative analysis of marginal bone level in millimeters relative to dental implant platform

DISCUSSION

The collected quantitative data were subjected to an initial descriptive statistical analysis in order to determine the main characteristics of the distribution, including mean values, median, standard deviation, and minimum and maximum values. In both groups, a considerable proportion of measurements showed a value of 0 mm, indicating the absence of detectable marginal bone loss in a subset of patients. At the same time, values ranging from 0.5 to 1 mm were also recorded, reflecting interindividual variability in the peri-implant bone response to implant therapy. For a more detailed interpretation of the data, frequency tables were constructed to illustrate the distribution of observations across different ranges of marginal bone loss. The initial analysis of the empirical data presented in the Table 1 of individual marginal peri-implant bone loss values (in mm) enables a detailed assessment of the distribution and variability of the studied parameter across the two observed groups.

The frequency analysis demonstrates that the highest concentration of cases in both groups is observed at values of 0 mm and 0.3 mm, suggesting a similar distribution pattern of marginal bone loss regardless of the type of abutment coating. In the test group, which includes implants with biocomposite-coated abutments, there is a clear clustering of values around zero. A substantial proportion of patients show no measurable bone loss (0 mm), indicating stability of the peri-implant tissues throughout the observation period. In addition, values of 0.3 mm are recorded, and to a lesser extent 0.4 mm and 0.5 mm, reflecting limited marginal bone resorption in a subset of cases. The distribution may be characterized as mildly positively skewed, with a predominance of low values and an absence of extreme outliers.

Table 1. Quantitative data of the measured marginal bone loss in both groups, expressed in millimeters.

Test group	Control group
0	0,3
0	0
0,5	0,3
0,3	0,4
0	0
0	0
0,3	0
0,3	0
0,3	0
0	0,3
0	0
0	0
0	1
0,5	0,3
0	0,3
0	0,5
0,3	0
0,4	0,5
0	0
0,5	0,3

The maximum recorded value in this group is 0.5 mm, which remains within the clinically acceptable range of post-implantation bone remodeling. In the control group, consisting of implants with uncoated abutments, a similarly high frequency of zero values is observed, indicating that a considerable proportion of patients also exhibited no measurable bone loss. However, compared to the test group, a greater dispersion of data and a wider range of variation are evident. In addition to values of 0.3 mm and 0.5 mm, a single case of 1 mm bone loss is recorded, which may represent an individual adverse tissue response. This higher value increases the overall spread of the distribution and contributes to a more pronounced asymmetry. A comparative overview of both groups reveals a broadly similar distribution pattern in terms of the prevalence of zero and low bone loss values (0–0.3 mm), which dominate the datasets. Mean values are expected to be low and comparable between groups, suggesting no substantial difference, a finding later confirmed by statistical analysis. In conclusion, the detailed evaluation of the primary data indicates that both groups are characterized by minimal or absent marginal bone loss one year after implant placement. The observed differences are mainly related to variability and isolated higher values in the control group, without a clear tendency toward increased bone resorption.

		test_group	control_group
N	Valid	20	20
	Missing	0	0
Mean		,1700	,2100
Std. Error of Mean		,04536	,05889
Median		,0000	,1500
Mode		,00	,00
Std. Deviation		,20287	,26338
Variance		,041	,069
Skewness		,539	1,474
Std. Error of Skewness		,512	,512
Kurtosis		-1,450	2,838
Std. Error of Kurtosis		,992	,992
Minimum		,00	,00
Maximum		,50	1,00

test_group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	11	55,0	55,0	55,0
	,30	5	25,0	25,0	80,0
	,40	1	5,0	5,0	85,0
	,50	3	15,0	15,0	100,0
	Total	20	100,0	100,0	

control_group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	10	50,0	50,0	50,0
	,30	6	30,0	30,0	80,0
	,40	1	5,0	5,0	85,0
	,50	2	10,0	10,0	95,0
	1,00	1	5,0	5,0	100,0
	Total	20	100,0	100,0	

Figure 2. Statistical analysis of the main distribution characteristics, including measures of central tendency (mean and median), measures of dispersion (standard deviation), as well as the minimum and maximum observed values.

Graphical analysis using histograms confirmed an asymmetrical distribution with clustering of observations around zero values, which is characteristic of clinical datasets where a substantial proportion of patients do not exhibit pathological changes. The analysis further indicated that values in the test group were closer to the thresholds of approximate normality, whereas the control group demonstrated more pronounced deviations, further highlighting distributional heterogeneity.

The results of the t-test ($p = 0.594 > 0.05$) indicated no statistically significant difference between the mean marginal bone loss values in the test and control groups. In summary, the statistical analysis consistently demonstrates that the use of biocomposite-coated abutments does not result in a statistically significant reduction in marginal peri-implant bone loss compared to standard abutments without such coating over the one-year follow-up period. Despite minor observed variations, these differences did not reach statistical significance, suggesting that the effect of the investigated factor, if present, is of limited clinical relevance or may require a larger sample size and/or a longer observation period to be demonstrated.

Group Statistics

N	Mean	Std. Deviation	Std. Error Mean
20	,1700	,20287	,04536
20	,2100	,26338	,05889

Figure 3. Independent Sample Test

CONCLUSION

In conclusion, the present study demonstrated no statistically significant difference in marginal bone resorption between the investigated groups. These findings are in line with current literature, which reports predominantly experimental and preclinical evidence regarding the beneficial properties of chitosan, including its antibacterial, biocompatible, and osteoconductive potential, as well as its ability to support cell adhesion and osteogenesis. However, the absence of a detectable clinical effect may be related to the limited duration of follow-up, which, although clinically relevant, may be insufficient to capture long-term changes in bone remodeling processes. Additionally, the relatively small sample size may have reduced the statistical power of the study, limiting the ability to identify subtle differences between groups. It should also be considered that marginal bone resorption is a multifactorial process influenced by several clinical and biological parameters, including surgical technique, prosthetic design, microgap presence, occlusal loading, and individual patient response. Overall, the results indicate that the use of chitosan-modified abutments did not lead to a statistically significant reduction in marginal peri-implant bone loss compared to conventional abutments within the one-year observation period.

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