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INITIAL MICROGAPS AT IMPLANT-ABUTMENT INTERFACE OF CAD-CAM ABUTMENTS FABRICATED BY TWO DIFFERENT MILLING STRATEGIES AND MACHINES (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: The micro gaps at Implant-Abutment interface can be colonized by bacteria affecting the remodeling of the peri-implant crestal bone and the long-term health of the peri-implant tissues.

AIM OF THE STUDY: To compare microgaps at the implant-abutment interface of CAD/CAM abutments fabricated using different milling machines and strategies.

MATERIALS AND METHODS: Three different types of abutments were be used in the study, Milled Abutments by Arum CAD/CAM system, Milled abutments by Emmar CAD/CAM system, and Stock Abutments. Each abutment type (n=6) was torqued into the corresponding implants. Stereomicroscope and scanning electron microscope were used to make micrographs perpendicular to IAI. An image processing program was used to measure the initial microgaps at IAI. Statistical analysis was done using one-way ANOVA followed by Tukey pairwise test.

RESULTS: Data were collected, tabulated, and statistically analyzed using appropriate test. . Emmar abutments had micrograps of 1.26 µm (SEM) and 2.24 µm (stereomicroscope), similar to stock abutments at 1.25 µm (SEM) and 2.22 µm (stereomicroscope). Arum abutments showed larger gaps at 2.51 µm (SEM) and 5.56 µm (stereomicroscope). IAI microgaps differed significantly ($p < 0.05$) in both analyses.

CONCLUSION: Emmar-milled abutments matched stock abutments in microgaps, while Arum-milled abutments had larger microgaps. Emmar-milled and stock abutments showed no significant difference but had smaller microgaps than Arum-milled.

KEY WORDS: Micro gaps, Abutment, Implant, peri-implantitis, milled Abutment.
RUNNING TITLE: Microgaps at IAI of CAD/CAM Abutments

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INTRODUCTION

Dental implants have become a popular treatment option for replacing missing teeth, owing to their high success rates and long-term stability. Dental implant systems typically consist of two components: the endosteal part (the implant), which is placed during the initial surgical stage, and the transmucosal connection (the abutment), which is usually attached after successful osseointegration of the implant (1,2). Marginal bone loss around the neck of a dental implant is a common complication post-implantation and can significantly affect the implant's long-term stability and success (3). Factors contributing to marginal bone loss include surgical trauma, peri-implantitis, occlusal overload, microleakage, biologic width, and implant anatomy at the crest area (4,5).

Microleakage at the implant-abutment interface (IAI) is a concern because it can lead to bacterial infiltration, potentially causing peri-implant disease (6). This microleakage is attributed to the presence of microgaps and micromotion at the IAI Microgaps are defined as the microscopic spaces

between the implant body and the corresponding abutment (7). These gaps can exacerbate micromovement and microrotation, resulting in fretting wear, screw loosening, and microbial leakage (8). Controlling micro gaps is facilitated by achieving an optimal initial fit between the abutment and the implant body, while minimizing micromovement requires both a precise fit and the mechanical stability of the implant connection (9).

Minimizing initial microgaps at the implant-abutment interface (IAI) is crucial for maintaining a stable implant connection, thereby preventing micromotion, microleakage, and screw loosening (8,10,11). However, initial microgaps are inevitable due to manufacturing tolerances, also known as the margin of error (12,13). Additionally, the machining process of both the implant body and the abutment must create a clearance fit to facilitate easy assembly. Increasing machining tolerances results in larger microgaps. Thus, the manufacturing process significantly impacts the initial microgaps at the IAI (14).

Stock abutments are prefabricated components available in a limited range of sizes and angles. They are manufactured by the implant producer using industrial-scale computer numerical control (CNC) milling machines with tight tolerances to ensure precision. In contrast, custom abutments are designed to mimic the shape and size of natural tooth abutments. Custom abutments offer several advantages, including improved esthetics, enhanced retention and resistance of the final restorations, and easier removal of excess cement (15).

Custom abutments are manufactured through various methods, with CAD-CAM technology gaining popularity in recent years. Modern milling machines can now fabricate custom abutments using different CAM programs and milling strategies, potentially leading to variations in surface finish and accuracy. Fluctuations in accuracy among products of dental CAD-CAM machines are attributable to differences in tolerances, which can affect the microgaps at the implant-abutment interface (IAI). Moreover, the quality of custom abutments produced by dental CAD-CAM may not be subject to rigorous quality control, increasing the likelihood of manufacturing errors and misfit (16).

The impact of various milling machines on the microgap at the implant-abutment interface (IAI) has not been investigated. This study seeks to compare the microgaps at the IAI for abutments fabricated using two CAD-CAM systems employing distinct CAM programs and milling strategies and comparing them to Stock abutments. By elucidating the influence of different milling machines on the microgap at the IAI, This research contributes to optimizing the design and manufacturing processes of abutments to improve implant outcomes. It emphasizes achieving a precise fit between the implant and abutment, particularly in cases requiring customized designs, such as angulation modifications. Furthermore, it aims to ensure that customized abutments achieve a level of accuracy comparable to that of stock abutments.

The aim of this study is to compare the microgaps at the implant-abutment interface of CAD/CAM abutments fabricated using different milling machines and strategies.

The null hypothesis of this study states that there is no significant difference in the initial microgaps between stock abutments and custom CAD/CAM abutments.

MATERIALS AND METHODS

Initial microgaps at the implant-abutment interface were assessed across three types of abutments: Stock abutments and milled abutments produced by 2 CAD-CAM systems: Arum, and Emmar. The implant system investigated in this study used butt joint connection.

Fabrication of CAD-CAM abutments

A Stock abutment was attached to a dummy implant and scanned using an extraoral scanner to obtain the approximate shape of the Stock abutment. The generated 3D file used to guide the design of the CAD-CAM abutments using a dental CAD program (Exocad GmbH). The CAD file and its corresponding configuration file exported to two CAM programs): a) Hyperdent to be used with Arum milling machine, and b) Sum 3D to be used with Emmar milling machine. Hyperdent CAM program contains an installed strategy formulated by the company itself, while milling strategy in SUM3D was adjusted by the operator by several trial and error, to fine tune the accuracy of the milling machine.

Assembly of implant bodies and abutments

An acrylic base was created for each implant body using a copper mold, ensuring the alignment of the implant body's long axis parallel to the external walls of the acrylic base. This alignment facilitated the capture of micrographs perpendicular to the implant-abutment interface (IAI). A total of 18 dummy implants (Legacy implant system by Implant Direct) were secured to the acrylic bases, and the corresponding abutments were torqued to 25 N using a torque wrench, following the manufacturer's instructions.

Evaluation of microgaps at IAI

The implant-abutment assemblies were evaluated for microgaps at the IAI using stereomicroscope (model Bx45; Olympus Corp. at x11 magnification), a scanning electron microscope (JEOL JSM-5300, JEOL Ltd.at x2500 magnification) and SED 20.0kv. An image processing program (Image J, NIH) was used to measure the IAI. The initial microgaps were assigned as the distance between the margin of the abutment to the shoulder of implant.

Statistical Analysis

Normality of initial microgaps was checked using Shapiro Wilk test, descriptives, and Q-Q plots. Normal distribution was confirmed thus data were mainly presented using mean, standard deviation, and 95% confidence Interval (CI). ***One Way ANOVA test*** was performed to compare between groups, followed by ***Tukey's post hoc test*** with Bonferroni correction to adjust for type I error due to testing multiplicity. All tests were two tailed and the significance level was set at p value<0.05. Data were analyzed using IBM SPSS for Windows, version 23, Armonk, NY, USA.

RESULTS

A statistically significant difference in microgaps at IAI was found between the two milled abutments (p<0.05) in both Stereomicroscope and scanning electron micrographs. There was no significant differences between milled abutments by Emmar and Stock abutments, however, both abutments showed statistically significant lower initial microgaps than milled abutments by Arum. (Table 1, Figure 1), (Table 2, Figure 2)

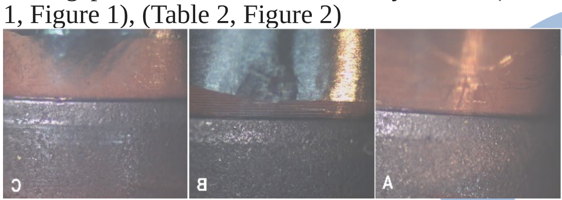

Figure (1): Images acquired using a stereomicroscope. (A) Stock abutment, (B) Abutment by ARUM, (C) Abutment by EMMAR

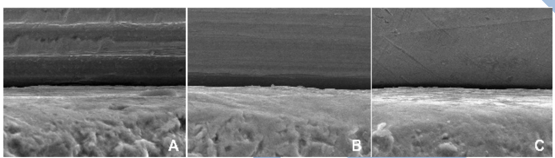

Figure (2): Images obtained through scanning electron microscopy (SEM). (A) Stock abutment, (B) Abutment by ARUM, (C) Abutment by EMMAR

Table (1): Comparison of microgaps at dental implant-abutment interface as measured by stereomicroscope between study groups

	Stock Abutments (n=6)	Milled abutments by Arum (n=6)	Milled abutments by Emmar (n=6)
Mean ±SD	2.22 ±0.19^{a}	5.56 ±1.01^{b}	2.24 ±0.33^{a}
95% CI	2.02, 2.42	4.50, 6.62	1.90, 2.58
Median	2.22	5.43	2.17
Min – Max	2.03 – 2.43	4.23 – 7.28	1.90 – 2.80
F Test (*p* value)	57.436 <0.0001*		

*Statistically significant difference at p value<0.05, CI: confidence interval, F test: One Way ANOVA

The same superscript letter means no significant difference.

Table (2): Comparison of microgaps at dental implant-abutment interface as measured by electron microscope between study groups

	Stock Abutments (n=6)	Milled abutments by Arum (n=6)	Milled abutments by Emmar (n=6)
Mean ±SD	1.25 ±0.02^{a}	2.51 ±0.21^{b}	1.26 ±0.02^{a}
95% CI	0.22, 0.27	1.30, 1.73	0.24, 0.28
Median	0.25	1.52	0.27
Min – Max	1.21 – 1.28	2.26 – 2.80	1.24 – 1.28
F Test (*p* value)	215.008 (<0.0001*)		

*Statistically significant difference at p value<0.05, CI: confidence interval, F test: One Way ANOVA

The same superscript letter means no significant difference.

DISCUSSION

This study aimed to evaluate the initial microgaps at IAI of 3 types of titanium abutments (Stock and milled abutments by two different milling machines). It was found that there were no significant differences between milled abutments by Emmar and Stock abutments, however, both abutments showed statistically significant lower initial microgaps than milled abutments by Arum. Therefore, the null hypothesis was rejected.

The microgaps at the implant-abutment interface (IAI) influence micromotion and microleakage between the implant and abutment, thereby affecting the implant's longevity (1,17). The presence of a microgap at (IAI) facilitates bacterial microleakage and exacerbates micromotion during functional loading (18-21). Both micromotion and microleakage contribute to fretting wear, plastic deformation, and screw loosening. These mechanical failures further enlarge the microgap and amplify micromotion, creating a vicious cycle that increases microleakage and mechanical damage (1,17,22). Together, these factors synergistically promote the infiltration of bacteria and endotoxins around the IAI, leading to marginal bone loss at the implant neck. Additionally, micromotion disrupts osseointegration by causing mechanical damage, further compromising implant stability (6,21,23).

An implant system with a butt joint connection was utilized, allowing the implant-abutment interface (IAI) to be directly scanned without the need for implant sectioning. The scanning process was performed using a stereomicroscope and an electron microscope. To ensure stability during scanning, the implants were embedded in resin blocks. Additionally, the microscope lenses were positioned perpendicular to the IAI to achieve accurate imaging (24).

The present study found that microgaps at the implant-abutment interface (IAI) for non-original milled abutments by Arum were significantly larger (2.51 ± 0.21 µm) than those for original abutments, whereas non-original milled abutments by EMMAR exhibited microgap dimensions (1.26 ± 0.02 µm) similar to original abutments. However, all the microgap values of the invstigated abutments are within the range reported in the literature (25). The findings of this study were aligned with a study by Duraisamy et al., which reported differences in microgaps at the outer point of the IAI between original and prefabricated third party abutments, ranging from 1.597 µm to 2.395 µm (24). Jakub Kowalski et al. observed microgap sizes varying from 0.1 to 3.7 µm for Astra implants and from 0.1 to 4.9 µm for Apollo implants (26). Similarly, Tsuge et al. reported microgap sizes ranging from 2.3 µm to 5.6 µm for both internal and external hexagon connections (27). Sola-Ruiz et al. established that acceptable limits for IAI microgaps are less than 10 µm. Consequently, all abutment types evaluated in this study fall within the acceptable range (28).

The study's findings have several clinical implications. Clinicians can use CAD/CAM milled abutments, as their fitting is comparable to that of original abutments. Additionally, the use of customized abutments can address prosthetic challenges associated with implants in various angulations. This study specifically evaluated the microgaps at the implant-abutment interface (IAI) for milled abutments. Notably, there is a scarcity of information on milled abutments in the existing literature, highlighting the need for further research in this area.

This study had certain limitations. Factors such as microbial leakage, cyclic loading, and fatigue testing, which may differentially affect the implant-abutment interface, were not included in this study's design. Additionally, the moist oral environment could influence these parameters differently compared to the dry testing conditions utilized in this study.

CONCLUSION

Milled abutments manufactured by Emmar demonstrated microgap dimensions comparable to those of stock abutments, whereas milled abutments produced by Arum exhibited larger microgaps in comparison to both stock abutments and those fabricated by Emmar. Both the Emmar and Arum-manufactured abutments exhibited microgaps that fell within the clinically acceptable range.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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