Compatibility of Nonoriginal Abutments With Implants: Evaluation of Microgap at the Implant–Abutment Interface, With Original and Nonoriginal Abutments

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Purpose: *The purpose of this study was to evaluate the fit of nonoriginal abutments to implants at the implant abutment junction.*

Materials and Methods: *Twenty titanium implants from a single manufacturer were randomly divided into 2 groups of ten each. Ten titanium premachined original abutments (group I) and ten titanium premachined nonoriginal abutments (from different manufacturer—group II) were connected to the implants with the recommended manufacturer torque level and then embedded into autopolymerizing clear acrylic resin blocks. After overnight curing, these blocks were vertically sectioned using water jet sectioning machine and evaluated under scanning electron microscope following the sequential cleaning procedures. The microgap at the implant–abutment interface for all the samples was measured using pixel counting software and subjected to statistical analysis using nonparametric Mann–Whitney* U *test.*

Results: *The mean microgap at the implant–abutment interface at the external, middle, and internal points was 1.597, 1.399, and 1.831 μm, respectively, for group I and 2.395, 2.488, and 3.339 μm, respectively, for group II samples. Nonparametric Mann–Whitney* U *test showed statistically significant difference between 2 groups at the midpoint for the nonoriginal abutments compared with the original ones.*

Conclusion: *Within the limitations of the study, the mean microgap at the implant–abutment interface at the platform level at the external, middle, and internal points for both original abutments and nonoriginal abutments was found to be within clinically acceptable limits. (Implant Dent 2019;28:289–295)*

Key Words: compatible abutment, implant–abutment junction, internal connection, misfit, scanning electron microscopy

Integrity at the implant–abutment interface plays an important role in reducing stress transfer to the bone, maintaining the screw joint stability and to prevent movements at the deep implant–abutment interface.[1–3] The implant–abutment interface determines the joint strength, lateral, and rotational stability.[4,5] Branemark's original external hex connection design was attributed to the short, vulnerable connection design that offered lesser resistance to lateral and rotational forces and reported screw joint complications and screw loosening ranging from 6% to 48%.[4,6] Currently, internal implant–abutment connection geometry is advocated because it could distribute occlusal forces deeper within the implant and protects the retention screws from excess loading and provides a strong and stable interface.[6,7]

In regular prosthetic protocols, premachined components are used to reduce the risk of mechanical complications.[8] Studies have reported lower microgap and misfit values for premachined abutments than with cast abutments.[9,10] In routine clinical practice, the restoring prosthodontist uses one particular system

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of implant and its original components including abutments and screws as supplied by the same manufacturer.[11] These components are thus from the original equipment manufacturer.[12] However, because of reasons such as nonavailability of the original implant components, lack of available knowledge, and limited access to equipment and for reduction of overhead costs in the dental clinic and/or laboratory, many clinicians adopt alternative solutions by using nonoriginal or equivalent components produced by a different manufacturer.[13–17] These nonoriginal components[15] are also referred to as compatible,[13] interchangeable[13,14,17], or after-market components.[12]

While choosing nonoriginal, premachined abutments, the design of the abutment joint should be carefully matched with that of the implant system.[13,15] Discrepancies greater than 10 μm are reported to result in bacterial infiltration and inadequate screw mechanics.[11] Functional performances of using nonoriginal abutments need to be evaluated to achieve higher prosthesis survival and success. Published research evaluating the misfit between implant–abutment interface using nonoriginal abutments is sparse.[11,14,17–20]

Various techniques for measurement of microgap at the implant–abutment interface have been reported, which include, direct observations of the implant–abutment interface performed by radiography,[21] scanning electron microscopy (SEM),[11,18,22–25] scanning laser microscopy[26] and optical microscopy,[7,27] 3D microtomographic technique,[28] and optical coherence tomography.[29] Among the methods to analyze the implant–abutment interface, SEM is a well-documented method that is reported to be an efficient method for this type of analysis.[30]

Furthermore, most studies on interface gap have focused on measuring the gap distance only at the outer circumference of the implant–abutment junctions.[2,11,14,17,23,25,26,31] Baumgarten et al[12] and Gubbi et al[32] have quoted this method as a limitation and have recommended conducting such analysis after mounting and cross-sectioning the assembled system to obtain a more comprehensive and extensive observation of the adaptation along the implant–abutment interface. Currently, studies comparing the implant–abutment interface while using original versus nonoriginal abutments by measuring at the interface in vertically sectioned test specimens are few.[4,19,20,33] Most of the studies have been based on using prefabricated versus computer-aided design & computer-aided manufacturing abutments of same manufacturer[4,19,33] or computer-aided design & computer-aided manufacturing of different manufacturer.[19,33] But, only one study was available comparing prefabricated abutments from same manufacturer versus prefabricated abutments from different manufacturer using internal hex connection design.[20]

Internal hexagon is one of the most popular connection designs in implant system. Many implant manufacturers provide implants with the same connection design and similar platform. This provides an opportunity to use prefabricated abutment of one implant system instead of prefabricated abutment of another implant system. In light of the above, the aim of the present *in-vitro* study was to comparatively evaluate the microgap at the implant–abutment interface with original and nonoriginal premachined abutments. The null hypothesis of this study was that, there would be no significant difference in microgap at the implant–abutment interface at the platform level when comparing original and nonoriginal abutments.

MATERIALS AND METHODS

Twenty titanium implants of internal hexagon connection design were randomly divided into 2 groups of 10 each (4.2-mm diameter, 10-mm length ADIN Dental Implants, Chennai, Israel). Ten implants from group I were connected to their respective premachined standard Ti abutments (Original: ADIN Dental Implants). Ten implants from group II were connected to premachined standard Ti abutments from a different manufacturer (Nonoriginal: MIS Implant Technologies, Ltd.).

Implant/abutment assemblies were embedded in a clear acrylic resin up to the implant crest level after its final set abutments were tightened to implant fixtures using torque wrench according to the manufacturers recommended torque level (35 N/cm) by holding in a Teflon implant stabilizing device followed by sandblasting of the abutments using alumina particles of 110-μm grit size (Korox, Alpha bond, Australia) to produce a uniformly microroughened surface and to facilitate retention of the abutment within the resin matrix during subsequent sample preparation procedures. The implant–abutment assembly was retorqued after 24 hours in a similar manner as described previously to ensure proper adaptation between the implant–abutment interfaces.

The implant–abutment assembly was completely embedded using clear autopolymerizing acrylic resin and allows to cure completely overnight. The embedded specimens were subjected to vertical sectioning using water jet–powered sectioning equipment (Germany), followed by sequential finishing procedures using progressively diminishing grit size (from 400 to 1200) of silicone carbide emery paper (3M India Ltd., Bangalore, India) followed by copious rinsing with distilled water (Merck & Co., Mumbai, India) and ethyl alcohol (Merck & Co.) to remove clogged debris that would interfere with accurate visualization of the implant–abutment interface. These were then cleaned using a steam cleaner (Confident dental equipment Ltd, Bangalore, India) and followed by cleaning in ultrasonic bath for 10 minutes (Beijing Ultrasonic Co., Beijing, China). Finally, all the test specimens were washed with ethyl alcohol and dried with a hair dryer (Panasonic Corporation, Bangkok, Thailand), resulting in completely cleaned and dry test specimens.

SEM

Each test sample was gold sputtered (K650 sputter coater, Quorum Technologies, Lewes, United Kingdom), before SEM procedures to make the samples more electroconductive, because SEM uses electrons and creates higher magnification and resolution images. The implant–abutment interface of each test sample was analyzed by scanning electron microscope S-3400N (Hitachi High Technologies Corporation, Tokyo, Japan) at 10-kV acceleration voltages (Fig. 1). In each sample, 6 points at the implant–abutment interface at the platform level, 3 each on the right and on the left sides, were selected for measurement (Fig. 2).

SEM photomicrographs were obtained (Department of Nanoscience in Madras University, Guindy) at higher magnifications in separate images to aid in accurate measurement of the interface microgap subsequently (×1000). The interface microgap was then measured on the scanning electron microscopic images obtained for each test sample using an image measuring pixel counting software (Image J, National Institutes for Health). The microgaps were then measured on the SEM images with the linear measuring scale of the software (Figs. 3, A and B).

Statistical Analysis

The data were subjected to statistical analysis using SPSS software for Windows 10.0.5 (SPSS Software Corp., Munich, Germany). Nonparametric Mann–Whitney *U* test was used for statistical analysis to compare the respective overall mean microgap values at the implant–abutment interface at the 3 different points, between the 2 test groups. *P* value < 0.05 was considered as significant.

RESULTS

Scanning electron microscopic images showing the microgap at the implant–abutment interface at the platform level of both test groups, and by using pixel counting software, the microgap at the implant–abutment interface at the platform level was measured at the external A [(a + a′)/2], middle B [(b + b′)/2], and the internal point C [(c + c′)/2] on the right (a′, b′, and c′) and the left sides (a, b, and c) for each sample of both test groups. These were considered as the basic data and were subjected to statistical analysis using nonparametric Mann–Whitney *U* test. It was found that the mean microgap value at the midpoint of group I (IB—1.399 μm) test samples was lesser than that of group II (IIB—2.488 μm) test samples, and this was found to be

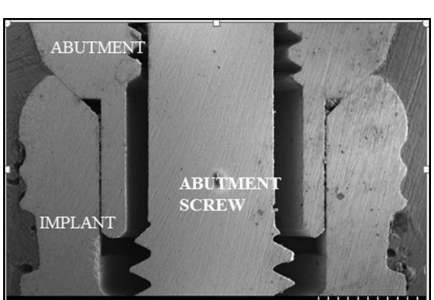

Fig. 1. SEM photomicrograph showing implant–abutment interface at ×30 magnification.

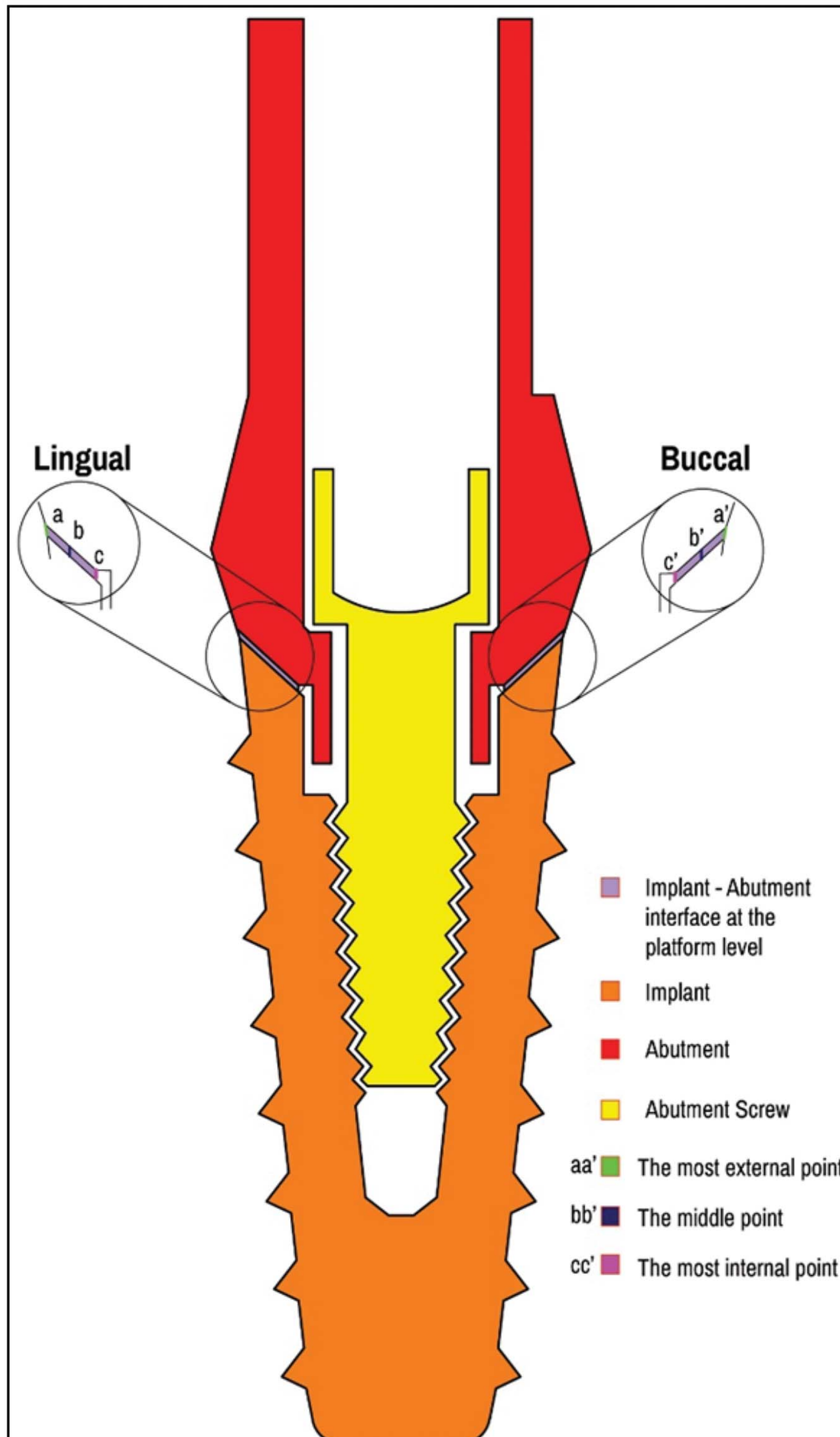

Fig. 2. Schematic CAD diagram showing implant–abutment interface with marked reference points at the platform level (right side—a′, b′, and c′, left side—a, b and c).

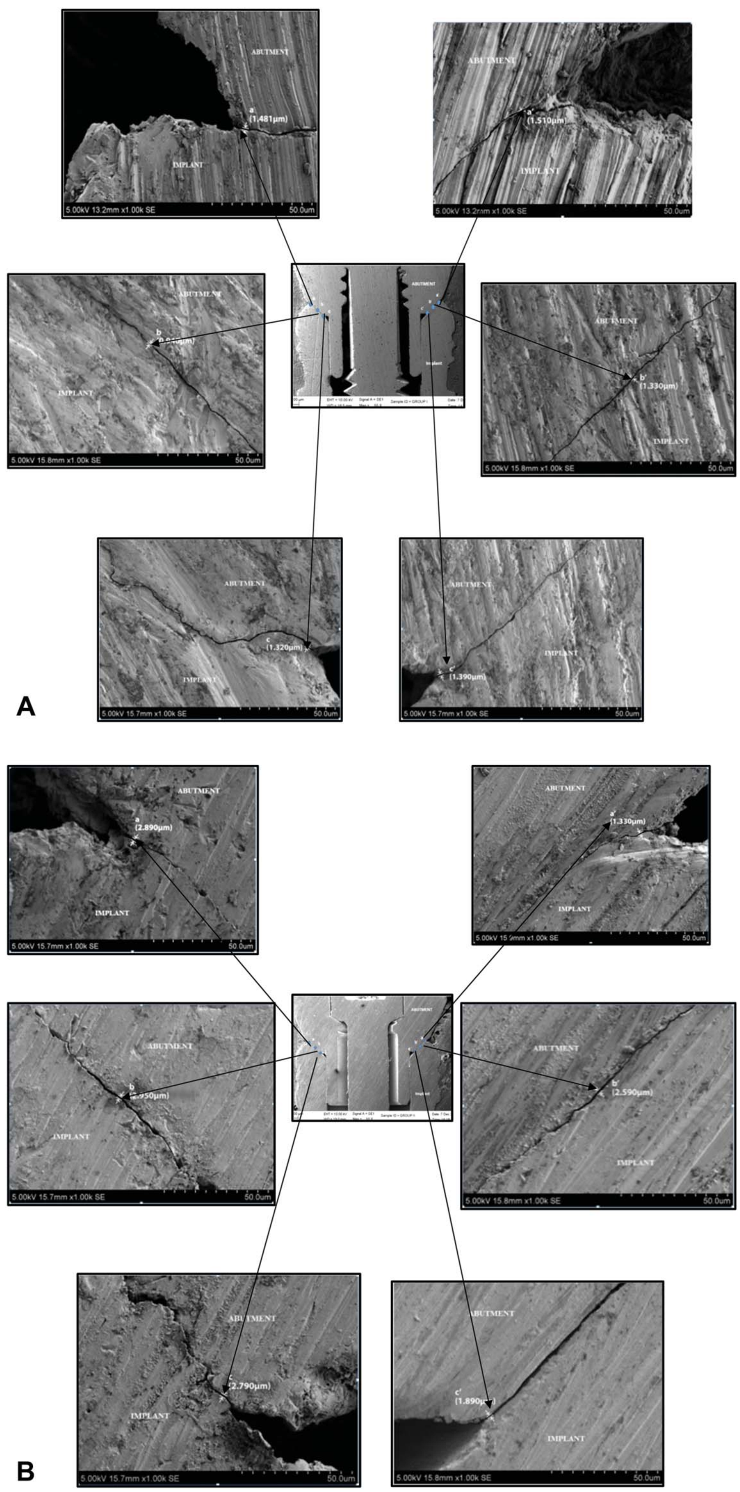

Fig. 3. (**A**) Measurement of microgap at the external (top right side a′: 1.510 μm, top left side a: 1.481 μm), middle (right side b′: 1.330 μm, left side b: 0.940 μm), and the internal point (down right side c′: 1.390 μm, down left side c: 1.320 μm) at ×1000 magnification of SEM photomicrograph (group I). (**B**) Measurement of microgap at the external (top right side a′: 1.330 μm, top left side a: 2.890 μm), middle (right side b′: 2.590 μm, left side b: 2.950 μm), and the internal point (down right side c′: 1.890 μm, down left side c: 2.790 μm) at ×1000 magnification of SEM photomicrograph (group II).

statistically significant (P value $<$ 0.05). No statistical significant was found in the other points between 2 groups. (Table 1 and Fig. 4).

The results of this study showed the following: The mean microgap at the implant–abutment interface at the external point was (IA): 1.597 μm for group I and (IIA): 2.395 μm, for group II samples. The mean microgap at the implant–abutment interface at the middle point was (IB): 1.399 μm, for group I and (IIB): 2.488 μm, for group II samples. The mean microgap at the implant–abutment interface at the internal point was (IC): 1.831 μm, for group I and (IIC): 3.339 μm, for group II samples (Table 1).

Nonparametric Mann–Whitney U test showed that the most external point and most internal point at the implant–abutment interface did not show statistically significant difference in microgap between original and nonoriginal abutments. Statistically significant difference was found only at the midpoint at the implant–abutment interface between original and nonoriginal abutments ($P < 0.05$) (Table 1 and Fig. 4).

DISCUSSION

The ideal vertical misfit would be no microgap.[8,34] However, previous studies on microgap assessment at the implant–abutment interface have ranged from 0 to 95.92 μm.[4,11,14,19–22,26,33–37] Among these studies, higher interface gaps have been observed in studies involving castable, cast on or milled abutments, with mean microgaps ranging from 1 to 95.92 μm,[8,18,24,25,34,36] and also in studies evaluating abutments with external connection designs with mean microgaps ranging from 0 to 49 μm.[11,14,24,26,35]

Studies involving premachined internal hex connections have yielded lesser microgaps ranging from 0 to 22.6 μm.[8,18,26,33,35] The results of this study have also yielded low microgap values for both original and nonoriginal premachined abutment groups, which is in line with these studies. This also corroborates that even premachined abutments can present microgap at the implant–abutment interface as

Table 1. Comparative Evaluation of Mean Microgap at the Implant–Abutment Interface at the External A (IA, IIA), Middle B (IB, IIB), and the Internal Point C (IC, IIC) for Both Group I and Group II, and Statistically Significant Result was Observed (*P** value—0.041) at the Middle Point (IB vs IIB) Between Group I and Group II

Reference Points	Group I and II, n = 20	Mean ± SD	*P*
External point	IA	1.597 ± 1.471	0.112
	IIA	2.395 ± 0.980	
Middle point	IB	1.399 ± 1.145	0.041*
	IIB	2.488 ± 1.529	
Internal point	IC	1.831 ± 1.628	0.082
	IIC	3.339 ± 2.036	

*P value < 0.05; significant.

suggested previously by Tavarez et al[8] and by Tsuge et al.[26]

Fujiwara et al[24] studied interface gaps in sectioned samples of castable external hex implants ranging from 0 to 15.267 μm while using implants and components of the same manufacturer when observed at the most external, middle, and most internal points at the platform level of sectioned specimens. This study also measured the interface gaps at the above mentioned reference points at the interface for internal hex connections using either original or nonoriginal premachined abutments after sectioning. The findings of this study reveal much lesser interface gaps in all the areas observed with both the abutment types than those obtained in the above study. This can be attributed to the differences in connection design (external vs internal design) and the mode of fabrication (castable vs premachined).

Both original and nonoriginal abutments in this study have shown insignificant differences in mean microgap at the external point of the interface at the platform level ($P > 0.05$). This area is the outermost area of the interface and vulnerable to microleakage and molecular leakage, and although the nonoriginal abutments show a higher mean interface value at this point (2.395 μm), it is statistically insignificant. Similarly, the mean microgap at the internal point of the interface at the platform level show statistically insignificant difference ($P > 0.05$), although the mean microgap at this point for nonoriginal abutments is higher (3.339 μm) than that obtained for original abutments. This indicates similarity in adaptation in these 2 areas of the implant–abutment interface for both original and nonoriginal abutments. The midpoint of the interface at the platform region showed a lesser and statistically significant value of misfit for original abutments (1.399 μm) as compared to nonoriginal abutments (2.488 μm). However, this mean microgap obtained for the nonoriginal abutments is also within the acceptable limits.[11,23,27] The reason for this need to be explored further in future studies and may be due to lesser number of samples included in this study.

The average dimension of a microbe is less than 2 μm, and hence, bacterial adhesion and colonization can be assumed in all implant–abutment interface configurations.[36] Thus lesser the microgap, lower is the risk of colonization and periimplant inflammation. Moreover, interface gaps <10 μm have been considered as acceptable with negligible or reduced biological and/or mechanical complications.[11] When viewed in this perspective, the mean microgaps at the implant–abutment interface at the platform level for all the reference points with both original and nonoriginal abutments are very low and within acceptable limits.[11,23,27] Thus, the null hypothesis of this study is validated.

Studies per se evaluating interchangeability of abutments with respect to implant–abutment interfaces are few.[11,13–15,17] Of these, 3 studies[11,14,17] have investigated the misfit using implants with external hexagon connection designs and have reported results ranging from acceptable compatibility[11,14] or limited compatibility within certain systems.[17] The results of this study revealed low and similar interface gaps with both original and nonoriginal abutments. However, these results cannot be extrapolated in totality to the results obtained with the above studies because of differences in connection design. The concept of using interchangeable abutments, however, seems to be acceptable based on the results of the above studies and this study.

Gigandet et al[15] and Berberi et al[13] investigated the interchangeability between abutments and implants with internal connection designs. Gigandet et al[15] reported that there was a significant difference in rotational misfit and failure mode between original and CAD-CAM abutments after fatigue testing. Berberi et al[13] reported significantly higher microbial leakage with premachined nonoriginal abutments as compared to the original abutments in implants with internal conical

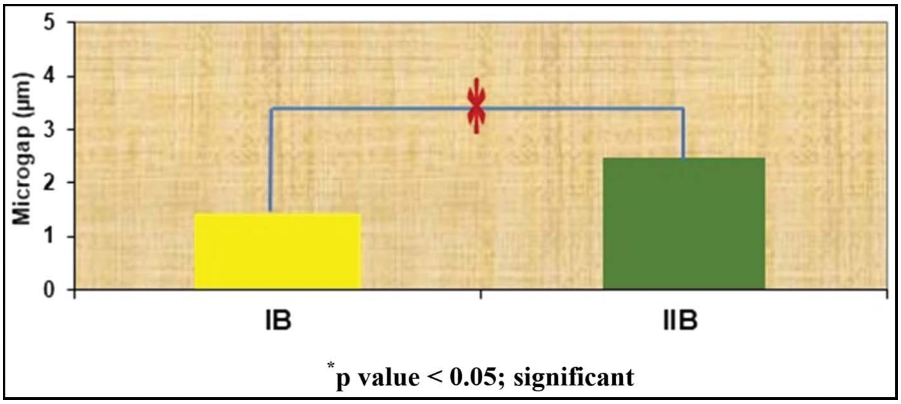

Fig. 4. The mean microgap at the implant–abutment interface at the middle point B was considered to be statistically significant (*P** value: 0.041*) between group I (IB—1.399 μm) and group II (IIB—2.488 μm).

connection design. In both these studies, vertical interface gaps were not evaluated to draw suitable comparisons with the results obtained in this study. Studies similar in design to this study are lacking in literature to enable further comparisons.

From the results obtained, from and within the limitations of this study, it can be concluded that the tested nonoriginal premachined abutment type can have a good compatibility with the implant system used in the study.

This study had some limitations. Parameters such as microbial leakage, cyclic loading, and fatigue testing may affect the interface differently and were not part of this study design. Furthermore, the moist oral environment may also impact these parameters differently than the dry testing conditions used in this study. One limitation with evaluating sectioned test samples is that these cannot be used to monitor changes in test conditions where measurements are required before and after testing. Also, the test groups can be expanded to include other nonoriginal abutments and/or connection designs. Future studies incorporating the above along with a larger sample size simulating in vivo conditions are recommended to add merit to the findings obtained with this study. Finally, the results cannot be generalized to the other implant systems.

Conclusion

In this *in vitro* study, all the mean values of microgap obtained at the 3 reference points were less than 10 μm for both original and nonoriginal premachined abutments, which is considered to be within the acceptable limit for misfit values. Thus, the null hypothesis of this study is validated. From the results obtained from and within the limitations of this study, it can be concluded that the tested nonoriginal premachined abutment type can have a good compatibility with the implant system used in the study.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

Approval

Institutional Ethics Board, Ragas Dental College and Hospital, Uthandi, Chennai (Number: 20161263).

Roles/Contributions by Authors

R. Duraisamy: research concept and design, sample collection, methodology, data collection, and preparation of manuscript. C. S. Krishnan: research concept and design, writing the article, data analysis and interpretation, and manuscript evaluation. H. Ramasubramanian: research concept and design, data analysis and interpretation, and manuscript evaluation. J. Sampathkumar: critical revision. S. Mariappan: critical revision. A. Navarasampatti Sivaprakasam: critical revision and final approval of article.

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