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Original Article

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Comparative analysis of microgaps in angled and straight components: a laboratory study

Análise comparativa de microgaps em componentes angulares e retos: um estudo de laboratório

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Resumo

Introdução: O protocolo de reabilitação com implantes dentários é uma opção de tratamento bem estabelecida para pacientes desdentados com alta taxa de sucesso. No entanto, existem fatores que podem levar à dificuldade de continuidade e até mesmo à perda completa da reabilitação. Microgaps são espaços encontrados entre o implante e o pilar protético que são causados pelo limite de precisão na fabricação do implante. Esse espaço pode causar micromovimentos e microinfiltração bacteriana que podem comprometer a vida útil do implante a longo prazo. **Objetivo:** Medir e avaliar microgaps em implantes angulados e retos usando microscopia eletrônica de varredura. Para a realização do estudo, foram utilizados um total de 30 implantes osseointegrados SIN®, sendo 15 retos e 15 angulados. **Material e método:** Para a análise comparativa desses componentes, foi utilizada a microscopia eletrônica de varredura, realizada por pesquisador devidamente calibrado e experiente. **Resultado:** Observou-se que as medidas de microgaps de ambos os componentes estão de acordo com os valores clinicamente aceitáveis apresentados na literatura, porém os valores de microgaps dos componentes angulados foram consideravelmente maiores em comparação aos componentes retos. **Conclusão:** Embora os valores apresentados corroborem os dados apresentados na literatura, estudos adicionais são necessários para uma compreensão mais abrangente e aprofundada da relação entre os microgaps dos componentes do sistema cone morse.

Descritores: Implantes dentários; projeto do implante dentário-pivô; odontologia.

Abstract

Introduction: The dental implant rehabilitation protocol is a well-established treatment option for edentulous patients with a high success rate. However, there are factors that can lead to difficulty in continuation and even complete loss of rehabilitation. Microgaps are spaces found between the implant and prosthetic abutment that are caused by the limit of precision in the manufacturing of the implant. This space can cause micromovements and bacterial microleakage that can compromise the long-term useful life of the implant. **Objective:** Measure and evaluate microgaps in angled and straight implants using scanning electron microscopy. To carry out the study, a total of 30 SIN® osseointegrated implants were used, 15 of which were straight and 15 angled. **Material and method:** For the comparative analysis of these components, scanning electron microscopy was used, carried out by a properly calibrated and experienced researcher. **Result:** It was observed that the microgap measurements of both components are in accordance with the clinically acceptable values presented in the literature, however the microgap values of the angled components were considerably higher compared to the straight components. **Conclusion:** Although the values presented corroborate the data presented in the literature, additional studies are necessary for a more comprehensive and in-depth understanding of the relationship between the microgaps of the morse cone system components.

Descriptors: Dental implants; dental implant-abutment design; dentistry.

INTRODUCTION

Dental implant rehabilitation has become a widely accepted and highly successful treatment option for edentulous patients[1-5]. As a result, various types of implants and therapeutic protocols have been developed. However, several factors can lead to the failure of the rehabilitation protocol. These include surgical trauma, peri-implant diseases, microleakage, variation in implant anatomy in the crest area, patient age, genetics, systemic conditions, and oral hygiene[6-8].

Due to its ability to protect the implant from unwanted loads during the bone consolidation phase, the two-piece implant protocol (implant and prosthetic abutment) is widely used. However, the implant and abutment cannot be perfectly aligned due to limitations in precision during their production[9]. As a result, a gap is created between the prosthetic abutment and the implant (implant-abutment interface). This gap can be a source of micromovements and bacterial microleakage, allowing microorganisms to pass freely between the oral cavity and the internal cavity of the implant[1,2,4-6,8-13]. The presence of bacteria is closely related to inflammatory processes that can lead to mucositis, peri-implantitis, and eventually bone loss[1-14].

The health of the soft tissues and the size of the implant-abutment interface strictly depend on the material of the prosthetic abutment, as well as its design, surface topography, and preparation[8]. Currently, most implants are made of titanium and its alloys[8-15], and according to Liu, Yang[9], the microgap in titanium implants is considerably smaller than in zirconia implants.

In different Morse cone implant systems, the degree of conicity and the connection area vary, which are primarily responsible for differences in bacterial penetration. The applied torque value is also important. Generally, a large connection area results in a small degree of conicity, and a high torque value translates to a low level of bacterial microleakage[9].

The most recommended technique for evaluating and measuring the implant-abutment interface is scanning electron microscopy (SEM)[6]. This technique provides high-resolution images with great depth of field of the object while maintaining a fixed and predetermined position[6]. Studies assessing microgaps in SIN implants are scarce in the literature. Therefore, the aim of this work was to evaluate and measure microgaps at the interface using SEM.

MATERIAL AND METHOD

This laboratory study evaluated the interface between the dental implant and the prosthetic abutment in order to measure the microgaps. It was conducted at the Department of Dentistry at the Federal University of Sergipe (UFS, Brazil), in collaboration with the Department of Physics and Materials Engineering.

Sample Characterization

A total of 30 osseointegrated SIN® implants (São Paulo, Brazil) were used, made of commercially pure titanium (c. p Ti), conforming to the NBR ISO 5832 standard[16], sized 3.8 x 11.5 mm with a Morse Cone prosthetic system. The samples were subdivided into two groups: 15 were coupled with straight abutments of AIMP 4003C-H 4.0 mm, and 15 were coupled with angled abutments of AIAM 4003C-H 4.0 mm and 3.0 mm.

Sample Analysis

For the comparative analysis of the microgaps in the samples, scanning electron microscopy (SEM) (JSM-6510 LV, JEOL USA, Inc) with an acceleration voltage of 5 kV was used.

Measurements were taken by a single, properly calibrated, and experienced researcher. SEM magnifications of 4,000 times were used, with captures obtained at the micrometer (μm) scale. Five areas (A1-A5) around the circumference between the component and the implant were analyzed. For each area, five measurements were taken, resulting in 150 measurements tabulated in Excel 16.0 (Microsoft, Washington, USA).

Statistical Analysis

The Shapiro-Wilk normality test was applied, and for comparison between groups, the Mann-Whitney test for independent variables was used. The significance level for all tests was set at 5% ($p \leq 0.05$). Data were analyzed using Bioestat 5.0 software[17].

RESULT

After the microscopy analyses, the microgaps were measured in micrometers and tabulated as shown in Figure 1. Figure 2 demonstrates a comparison of the size of microgaps from the t-test results, showing that the angled components have larger microgap values than the straight components. The sample group of angled components (CA) and the sample group of straight components (CR) were analyzed separately and comparatively.

Table 1 shows the results of the Shapiro-Wilk test and presents the mean microgap values separated by groups (A1 to A5), their standard deviation, and the p-value. It is notable that the mean values at the ends of both components are higher than their average values, but the discrepancy is more pronounced in the straight components. Regarding standard deviation values, a similar pattern to the mean microgaps is observed; however, in angled components, the standard deviation values are more standardized regardless of the region.

Table 2 shows the results of the normality Lilliefors test p-value and presents that the p-values are <0.05, then the data follow a normal distribution. Table 3 shows the results of the Mann-Whitney test for independent samples, which present different p-values for each sample. The p-value of the one-tailed test suggests a significant difference between the samples, indicating that one tends to be larger or smaller than the other. The p-value of the two-tailed test is not small enough to indicate a significant difference in general between the sample distributions.

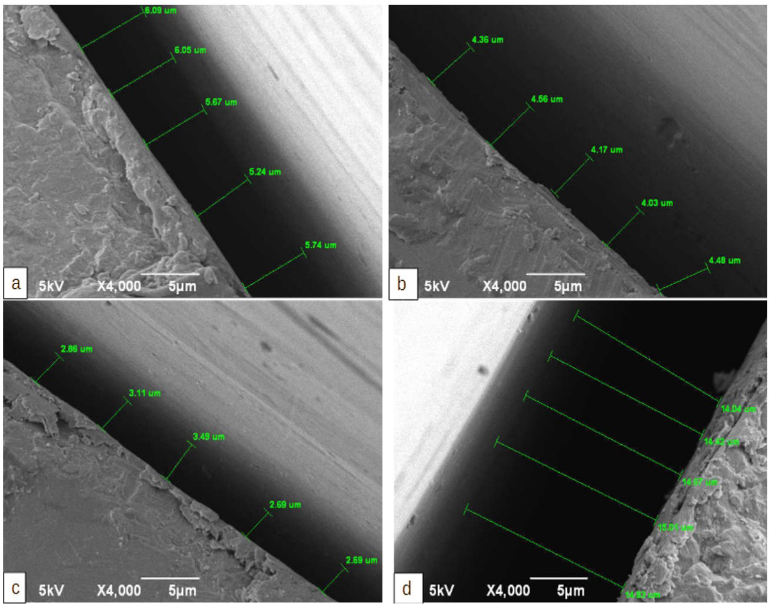

Figure 1. SEM analysis of the straight prosthetic component in different regions demonstrating the microgap between prosthetic abutment and implant in a magnificence of 4000 times.

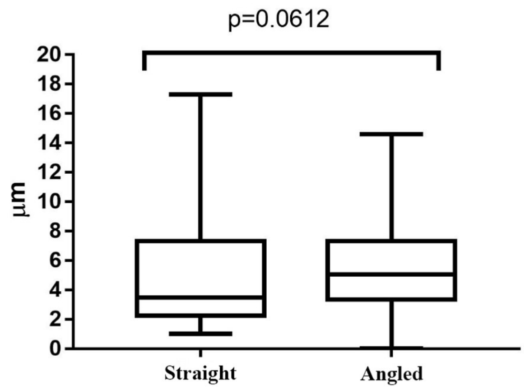

Figure 2. Comparison of microgap sizes between straight and Angled Components.

Table 1. Descriptive Analysis within Samples for Angled and Straight Components. Shapiro-Wilk Test.

Straight Component				Angled Component			
	Mean	SD	p value		Mean	SD	p value
A1	7.3380	±2.5102	0.7145	A1	6.2860	±2.3263	0.0337
A2	2.9513	±0.9771	0.2669	A2	5.5413	±3.1729	0.0092
A3	2.1907	±1.0405	0.1248	A3	4.1247	±2.9165	0.0945
A4	3.5653	±2.2232	0.0356	A4	5.3820	±3.8911	0.0413
A5	7.7953	±3.6814	0.3110	A5	6.3933	±3.4407	0.7817

SD = Standard Deviation

Table 2. Inter-sample Analysis for Angled and Straight Components. Non-parametric Sample Analysis.

Normality lilliefors test p-value	
Angled	< 0.01
Straight	< 0.01

Table 3. Inter-sample Analysis for Angled and Straight Components.

Mann-Whitney Test for Independent Samples	
p-value (one-tailed)	0.0307
p-value (two-tailed)	0.0615

DISCUSSION

The long-term success of dental implant rehabilitation demonstrates the effectiveness of this treatment option[1-5]. However, risks such as material manufacturing defects, surgical errors, and anatomical variations can impede the success of the rehabilitation[6-8]. Therefore, the connection between the implant and the prosthetic abutment should be as closely aligned as possible to avoid large gaps, thereby preventing micromovements and bacterial microleakage[1-2,4-6,8-13]. In this context, the images produced in our study using SEM reveal the presence of minimal microgaps in SIN implants, both in straight and angled components.

In the Morse Cone connection, fixation and stability depend not only on the fixation screw but also on the friction between the conical parts and the surface of the component[18]. Emphasizing the importance of the absence of microgaps at the implant/component interface, our study presents the quantification of existing microgaps and their variations within the same manufacturer.

This study demonstrates higher average microgap values in the uppermost region (A1) and the lowermost region (A5) for both straight and angled components, with a greater discrepancy between the values at the extremities (A1 and A5) and the central regions (A2, A3, and A4) in straight components. These values contradict the findings of Duraisamy et al.[19], who observed smaller values in the upper region and larger values in the lower region, which could be explained by differences in implant designs and brands. Lopes et al.[20], in their study of Neodent® implants, reported average values similar to the straight components in our research. However, the maximum values in our study are relatively higher, regardless of the component type. On the other hand, the average values reported by Costa et al.[6] differ from those presented in our study, with differences in implant design and brands likely being a determining factor for this discrepancy.

After analyzing the statistical data, it can be observed that the microgaps present in this study are within clinically acceptable standards for the joining of components. Aspects such as the precision and stability of the connection between components and implants have been the focus of research by manufacturers aiming to improve the quality of mechanical parts through enhanced machining processes, resulting in greater precision. Additionally, investments in materials that support or minimize screw loosening have been reported in the literature[18].

Mohammadi et al.[11] state that when the abutment is connected to the implant, gaps between the components are inevitable and can become potential sites for bacterial microleakage, which may lead to the infiltration of inflammatory cells. This inflammatory process around the implant can cause peri-implantitis and even bone loss, ultimately affecting the long-term success of the rehabilitation[21,22]. However, studies by Kowalski et al.[8], Duraisamy et al.[19], Jemt, Book[23], and Solá-Ruíz et al.[24] demonstrate that microgaps of less than 10 micrometers do not have harmful effects on either soft or hard tissues. Comparing with our study, it can be concluded that the average microgap values are satisfactory since they are below 10 micrometers. Additionally, due to the stability of the Morse cone system, oxidation between the components is observed in the gap region, similar to cold welding, which sometimes acts as an effective physical seal, preventing bacterial proliferation[6].

When comparing the average values between these components, a notable disparity is observed in the central regions (A2, A3, and A4), where the values for angled components are significantly higher. This discrepancy can be attributed to the unique design characteristics of these components. Conversely, the average values at the extremities (A1 and A5) between the straight and angled components are similar. Additionally, we identified that some of the analyzed regions did not exhibit parametric distribution, suggesting the possibility of irregularities that could affect the implant adaptation.

In the two-piece implant system, although micromovement in conical connections decreases due to precise manufacturing of the implant and abutment, the current production process cannot eliminate micromovement entirely. A limitation of this study include that the microgap was evaluated in the absence of loading mechanics. Future studies should assess the microgap under the combined application of dynamic mechanical testing and fatigue, where micromovements produced by chewing could lead to significant micro-adaptations between the abutment and implant that are important for clinical practice.

CONCLUSION

In light of the above, we can conclude that microgaps are present in both straight and angled components, and they are within clinically acceptable limits. The results show higher microgap values in the angled component group, suggesting conformational changes related to manufacturing. Additional studies are needed for a more comprehensive and in-depth understanding of the relationship between microgaps in Morse cone system components.

AUTHORS CONTRIBUTION

Yuri Lins Lobo: Data curation, writing of the original manuscript, design of data presentation, data analysis and validation of data and experiments.

Giovanna Nascimento Mendes: Writing of the original manuscript, design of data presentation, data analysis and validation of data and experiments.

Lucas Alves da Mota Santana: Proofreading and editing.

Lara Gois Floresta: Proofreading and editing.

Antônio Carlos Marqueti: Conceptualization, implementation and testing and methodology.

Wilton Mitsunari Takeshita: Conceptualization, implementation and testing and methodology.

Cleverson Luciano Trento: Conceptualization, data curation, methodology, implementation and testing and supervision.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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