Int. J. Odontostomat.,
15(2):356-362, 2021.

Evaluation of tensile strength after insertions andremovals of abutments on frictional Morse taper implants

Evaluación de la Resistencia a la Tracción Después de la Inserción y Extracción de Pilares en Implantes de Cono de Fricción Morse

Jader Moreira da Silva[1]; Brenda Santos Sobral[1]; Carolina Takis Cabral[1]; Cíntia de Melo Silva Souza[1]; Ricardo Roberto de Souza Fonseca[2] & Juliana Cama Ramacciato[3]

DA SILVA, J. M. Evaluation of tensile strength after insertions and removals of abutments on frictional Morse taper implants. *Int. J. Odontostomatol.,15(2)*:356-362, 2021.

ABSTRACT: This study aimed to evaluate possible changes in final retention after nine sequences of insertion and removal (SIR) of a frictional Morse taper implant/abutment system, evaluating the force required for dissociating this set between sequences, and verifying possible deformations in the implant heads. Ten implants, 13 mm long and 3.3 mm in diameter, were coupled to a universal mechanical testing machine. Ten anti-rotational abutments, 13 mm long and 3.5 mm in diameter, were connected to the implants parallel to the long axis, using an instrument called beat-connection, and subjected to tensile tests and SEM analysis. The results were analyzed using the Kruskal-Wallis test with Dunn’s post-test, and the significance level was set at 5 %. There was no statistically significant difference in final retention among the nine SIRs evaluated. The force needed to uncouple the abutment from the implant increased as SIRs were performed on all ten implants, and an increase of 29.03 % was observed in the ninth SIR compared to the first SIR. After SEM analysis, no significant deformations, fractures, or cracks were observed in the implant heads.

KEY WORDS: Tensile strength, Dental implant, Friction, Dental Implant-Abutment Design, Dentistry.

INTRODUCTION

Oral rehabilitation with dental implants is an alternative treatment that benefits patients when well planned. Different interfaces between implants and prosthetic abutments were developed with the aim of obtaining better performance before functional occlusal loads1 that provide clinical longevity (Zielak *et al*., 2011; Aguirrebeitia *et al*., 2013).

Different forms of connections between implants and abutments, such as external hexagon, internal hexagon, and Morse taper, are used nowadays (Mangano *et al*., 2009). Morse taper implants provide better adaptation between the abutment and the implant and eliminate gaps between them, thus reducing levels of peri-implant bone resorption and minimizing micromovements. Loosening of the abutment/prosthesis set is less frequent in Morse taper connections than in other types of connections (Mangano *et al*.; Zielak *et al*.; Aguirrebeitia *et al*., 2013; Zipprich *et al*., 2018). Moreover, this system is reported to have a high success rate (Dibart *et al*., 2005).

Morse connections can also be classified into the following two types: the first type is one where the fit between the abutment and the implant is made using a screw and the second type, called true Morse taper system, is where the fit is made only by the taper and its connection is exclusively frictional (Rack *et al*.,

1 University Center of State of Pará, department of dental implant, Belém, Pa, Brazil; https://orcid.org/0000-0003-2667-9739.
2 Federal University of Pará, Laboratory of Virology, Institute of Biological Sciences, Belém, Pa, Brazil; https://orcid.org/0000-0003-0312-0553.
3 São Leopoldo Mandic Institute, Faculdade São Leopoldo Mandic, department of dental implant, Campinas, Sp, Brazil; https://orcid.org/0000-0002-3081-1504.

Received: 2020-10-28 Accepted: 2020-12-27

2010). The true Morse connection, called frictional union or frictional Morse taper implant (FMTI), is found in some implant systems and does not use screws. It is placed on the long axis of the implant using beats to protect the frictional resistance and provide resistance to displacement (Dibart *et al*.; Rack *et al*.; Aguirrebeitia *et al*., 2014).

The FMTI has some advantages, such as the possibility of adequate aesthetics in the cervical region and a lower number of prosthetic components, with consequent reduction of costs, ease in clinical procedures, and increased resistance to fracture of the prosthetic abutment (Rabelo *et al*., 2015). Stability of the abutment is fundamental to achieve aesthetics and longevity of the prostheses, which is fundamental to the success of and satisfaction with the rehabilitation (Rack *et al*.; Aguirrebeitia *et al*., 2014; Rabelo *et al*.). Although this system promotes interlock between the components, the professional may need to remove the abutment for some reason.

If this occurs, the question is whether this procedure would compromise the retention of the abutment to the implant. Moreover, deformation of the Morse taper could occur after several loosening events (Feitosa *et al*., 2013; Rabelo *et al*.). Therefore, the present study aimed at evaluating the tensile strength of frictional Morse taper implants of a specific brand after a sequence of insertions and removals (SIR), as well as evaluating possible deformations in the head of the implants using scanning electron microscopy (SEM).

MATERIAL AND METHOD

Study population. This study was designed as an in vitro analysis of frictional force insertion and removal (SIR) upon abutments in morse taper implants. The sample size was calculated according to the PD (mean and standard deviation) and the level of significance was 5 %, with an effect of 0.80. Considering a statistical power of 95 %, the sample size was fixed in 10 morse taper implants.

The insertion and removal tests were based on the study of Zielak *et al*. The sample tests were conducted by a single Calibrated Researcher (C.R.1), who had previously experience in clinical and in vitro studies. The SIR testes results were analyzed by scanning electron microscopy (SEM) by another C.R.2 who had previously experience SEM analysis. All the images obtained from SEM were compared to newly control implants, the analysis occurred between August 2017 and December 2018.

Sample preparation. 10 titanium frictional morse taper implants of 11 mm in length and 3.3 mm in diameter (Kopp, Curitiba, Brazil), with Morse taper prosthetic interfaces, and 10 anti-rotational abutments of 13 mm in length 3.5 mm in diameter (Kopp, Curitiba, Brazil) were used (Fig. 1). The implants and the abutments were made of titanium alloys (ASTM F67 and ASTM F136, respectively), with hardness values of 20 HRC and 29 HRC. All implants and abutments surfaces were manufactured in a Swiss lathe using hard metal inserts. The internal calibration was verified by C.R.1 using standard methods cited by Zielak *et al*. After the internal calibration all abutments and implants were passively mounted together by C.R.2 prior to the application of force, with rounding up to a total of 10 implant- abutment mounts.

Fig. 1. implant and anti-rotational abutment.

Base to be coupled in the universal test machine (BCUTM): its shape had a cylindrical body and surface, with the upper portion having a larger diameter than the body, and it had a drill hole in the center with thread pitches for coupling the fastener of the specimens. In the lower portion, there was a hole to lock the BCUTM in the test machine (Fig. 2).

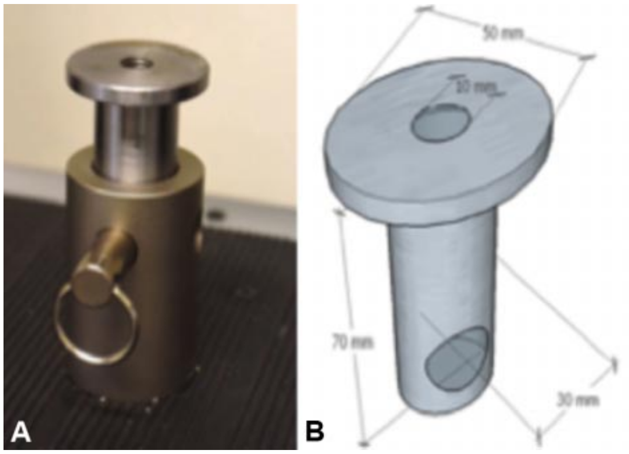

Fig. 2. A - Representation of the Diagram of the Base to be coupled in the universal testing machine B - Attached base.

Specimen fastener (SF): used to connect the implants. It had an external hexagonal shape and a cylindrical central hole on its surface, with thread pitches similar to the ones of the implant used. In the lower portion, the SF had a cylindrical screw to connect itself to the BCUTM through threading (Fig. 3).

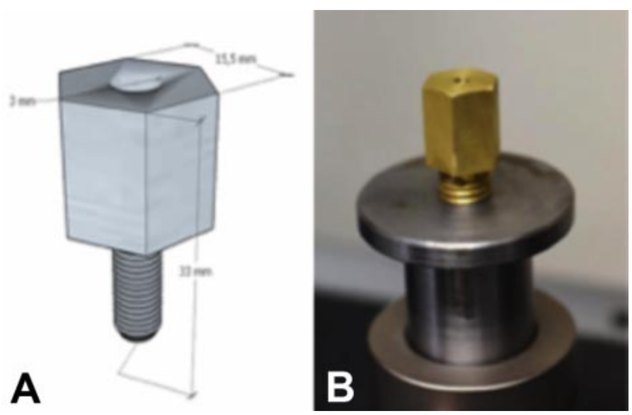

Fig. 3. Representation of specimen fastener and the same one coupled to the BCUTM.

The implants and the abutments were removed from their package one by one, and the implants were threaded into the SF. Then, they received the abutments, with a light digital pressure without force, always by the same operator, making a total of 10 specimens (implant/abutment). Next, the abutment was attached to the implant by means of an impact instrument, beat-connection (Kopp, Curitiba, Brazil), parallel to the long axis of the implant/abutment (IA), with three attachments (corresponding to the three beats for abutment fixation to the implant) in each SIR, as recommended by the manufacturer, and then subjected to the tensile strength tests (Fig. 4).

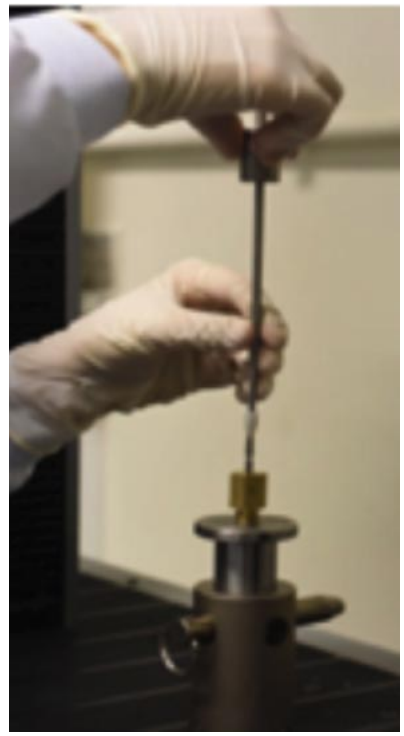

Fig. 4. Attachment of the abutment to the implant.

Tensile strength test. The tensile strength test was performed at the University of the State of Pará (CESUPA), using a Kratos universal mechanical testing machine model KE 2.000 MP (Cotia, SP, Brazil). A handcrafted device to be coupled in the neck of the abutment was used for the verification of the removal force. This device was called a hitch (Fig. 5), which consisted of a hollow, cylindrical metal object with a lower portion having an aperture of the size of the cylinder radius and a width of 2 mm, sufficient to be hitched to the abutment neck. The upper portion had a ringto be connected to a hook that was attached to a load cell (model CKS – Kratos; Cotia, São Paulo, Brazil), with a capacity of 50 kgf.

After the interlock in the abutment neck, the tensile tests were performed at a displacement speed of 0.50 mm/min until the abutment decoupling was achieved. Then, a new attachment (three beats), and a new tensile strength test were performed. This process was repeated nine times. Each of these repetitions was called SIR, referring to the sequence of insertion and removal. The measure of the decoupling force (separation of the abutment from the implant) was transmitted to a computer that provided the value in Newtons (N) from a specific software of the universal mechanical testing machine.

Fig. 5. Hitch/ hook positioned in the abutment neck to perform the traction test.

Statistical analysis. For the analysis of the values obtained for the tensile strength tests (in Newtons), the results were tabulated for mean values, standard deviation (SD), and percentage of decoupling force increase of the IA set (%DFIIA).

Given the non-normal distribution of the data evaluated by the Shapiro-Wilk test, the Kruskal-Wallis analysis with Dunn's post-test were performed for the statistical treatment of the results, in which the difference between the SIRs was evaluated (a = 0.05). The significance level was set at 5 %.

As a complementary analysis, a calculation was made of the percentage (%) of decoupling force increase of the implant and abutment set (% DFIIA), from the formula:

$$\%DFIIA = \frac{(SIRF-SIR1) \times 100}{SIR1}$$

SIRF = Final sequence of insertion and removal
SIR1 = Initial sequence of insertion and removal

Scanning electron microscopy analysis. The ten implants were subjected to scanning electron microscopy (SEM) analysis and compared to two new implants microscopically. The implants were pre-metalized with gold for 1.5 minutes on an Emitech model K550X metalizer (Ashford, Kent, England). Secondary electron images were obtained from the Microanalysis Laboratory of the Institute of Geosciences (IG) of the Federal University of the State of Pará (UFPA). The equipment used was a Zeiss SEM model EVO-MA-10 (Jena, Thuringia, Germany).

The operating conditions were electron beam current = 100 mA, constant acceleration voltage = 10 kV, working distance = 11 to 12 mm. The images of the head of the implants used after the tensile test, as well as the control implants, were saved in JPEG format, analyzed, and compared for the search for possible deformations.

RESULTS

The null hypothesis (Ho) was accepted, that is, there was no significant statistical difference between the SIR numbers and the final retention. Thus, the safety of retention of the prosthesis can be obtained from the first insertion of the abutment to the implant until the ninth one, as demonstrated in this study.

Table I shows the mean of the SIR 1 to SIR 9 and the mean of their standard deviations, respectively. Equal letters mean similarity between the groups that contain them. Therefore, these groups behave similarly and, thus, there is no difference between them.

An increase of 29.03 % in the ninth SIR (SIR9) was observed compared to the first SIR (SIR1) when analyzing the decoupling force increase between the implant/abutment set (%DFIIA). Thus, SIR1 was the basis for comparing the other eight SIRs (Fig. 6).

Table I. Mean values in (N) of the sequences and respective standard deviation (SD).

Implant	SIR1	SIR2	SIR3	SIR4	SIR5	SIR6	SIR7	SIR8	SIR9
MEAN	177.7±	176.40±	186.45±	197.61±	212.56±	212.29±	217.25±	217.51±	222.54±
GROUP	35.07	54.16	36.18	41.51	46.17	38.56	31.47	18.74	21.10
SD	A	A	A	A	A	A	A	A	A

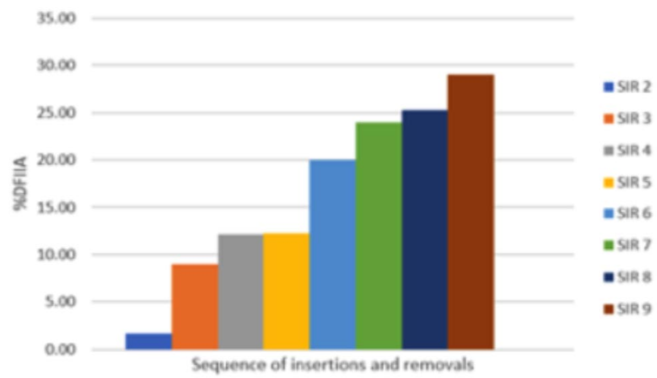

Fig. 6. The graphic shows the percentage of force required to decouple the abutment in each SIR.

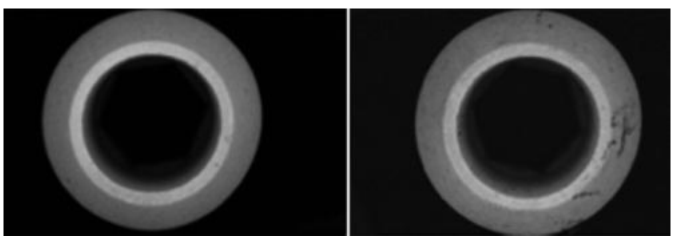

Fig. 7. Scanning electron photomicroscopy of the control implant (left) with the implant subjected to the tests (Radiation source: monochromatic Al Ka; kV levels: 10 kV; Magnifications: 1000X; Filter: polycarbonate).

Figure 7 shows the SEM image of a new implant compared with an implant after the mechanical test. No significant deformations were evident, and only small marks of contact in the direction of the abutment attachment were observed.

DISCUSSION

In this study, we evaluated the possible changes in final retention of the abutment to the Kopp frictional Morse taper implant and the necessary force for dissociating the implant/abutment set (IA) between the SIRs. We also sought for possible deformations of the head of the implant. After the 9 SIRs of the abutment to the implant, there was no loss of retention. Therefore, if it is necessary to remove and replace the abutment during installation andmaintenance of the prosthesis, the final retention will not be impaired. As the SIRs were made, the decoupling force increased, which proves that in the screwless system the higher the number of attachments, the higher the tensile strength and, consequently, the greater the retention (Bozkaya & Müftü, 2003; Moon *et al*., 2009; Schmitt *et al*., 2014).

Kopp friction system consists of a cylindrical abutment with less than 2° between the inner walls of the implant and the outer walls of the abutment, which when coupled to the implant requires a removal force greater than the insertion force (Steiner *et al*., 2009; Ricciardi Coppedê *et al*., 2009; Rabelo *et al*.). This Morse taper interface is related to the phenomenon of cold welding, which occurs through the intimate contact between the surfaces of the prosthetic abutment and the implant, leading to an interlock between the parts and, consequently, greater friction retention and stability (Steiner *et al*.). The high frictional force comes from the high-pressure contact by sliding the two surfaces. Consequently, the oxide layers break, and the roughness melts as cold welding (Ricciardi Coppedê *et al*.).

Zielak *et al*. analyzed implants of the same length and different diameters in a five-fold sequence of insertions and removals, and their result was similar to that of the present study, showing a positive correlation between the sequence number and the removal forces. The mean value of removals was increased from T1 (111.4 N) to T5 (294.6 N), and the highest value was 53.2 %, between the first and the second measurements (Zielak *et al*.). In this study, 9 SIRs were performed, with the objective of extrapolating a possible number of abutment removals. In this proposal, the sequential increase of the removal force was obtained, reaching 29.03 % between the first and ninth sequences.

The present study showed an association between the number of insertions/removals and the decoupling force increase of the IA set. The mean removal values ??were sequentially increased from sequence two (SIR2), 176.40 N, with 1.61 % of DFIIA to sequence nine (SIR9), 222.54 N, with 29.03 % of DFIIA.

According to Bozkaya & Müftü, during the insertion of the abutment, elastic deformation occurs with consequent plastic deformation. The authors state that a certain degree of plastic deformation increases the extraction force of the abutment due to the increase of the insertion depth and concluded that the mechanical characteristics that the tapered connections, such as the insertion and removal forces, besides the distribution of forces by the abutments depend on the taper angle, the length of the contact area, the internal and external diameters of the abutments, the depth of insertion of the abutment, the properties of the materials and the coefficient of friction of the contact surfaces (Zielak *et al*.).

Similarly, the greater the activation force over the long axis of the implant the greater will be frictional retention (Bozkaya & Müftü; Moon *et al*.; Steiner *et al*.; Ricciardi Coppedê *et al*.; Schmitt *et al*.). Therefore, the more force applied to the prosthetic abutment, the more likely it is to intrude into the implant, thereby having a more intimate contact between the implant and the abutment and causing them to act physically as if they were a single body, which can be, thus, clinically relevant during the distribution of masticatory loads.

Based on the literature, masticatory forces under physiological conditions in natural teeth can range from 10 N to 120 N, and the highest maximum forces vary from 190 N to 290 N in anterior teeth and from 200 N to 360 N in the region of the molars (Moon *et al*.). In tapered interface implants, the occlusal compression force acts in the direction of insertion of the abutment, favoring the auto-attachment in the implants (Steiner *et al*.). In this way, masticatory forces influence the retention of the prosthetic abutment to the implant, since the chewing movements cause intrusion forces more expressive than those of extrusion and laterality. A continuous attachment of the exclusively frictional abutments could still occur over time (Bozkaya & Müftü). Thus, a removal force greater than that observed in the present study may be required.

According to the manufacturer of this Kopp biological friction system, the correct attachment of the prosthetic abutment to the implant should be done at the long axis of the implant, that is, at 0º (Feitosa *et al*.). This study followed the manufacturer's indication for angulation and no other angulation was performed for analysis. However, it is possible to find difficulties in the angulation indicated during the attachment in the mouth, due to the limitation of mouth opening or even the positioning of the teeth. The literature shows that the attachment of the prosthetic abutment at a 30º inclination shows a lower resistance to decoupling when compared to the attachment at the long axis of the implant/prosthetic abutment, which is 0º (Zielak *et al*.). Thus, it is observed that the retention is reduced for a 30º angulation, evidencing that a sub-attachment may cause a higher index of mechanical failure, such as the loosening of unitary prostheses (Zielak *et al*.).

Even though the retention was not statistically relevant in the present study, it should be emphasized that the force for removal increased with each SIR and, therefore, it can be clinically more difficult to manipulate the abutment. The abutment should receive a greater force made by the dental surgeon, who will have to look for angles and shapes to remove this abutment so as not to cause injuries to teeth or tissues adjacent to the area of the implant/abutment set, thus avoiding discomfort to the patient (Zielak *et al*.).

Samples evaluated by SEM at the end of SIRs showed small marks resulting from the friction where the implant contact the abutment, which may not interfere in the final retention of the IA set. No cracks or fractures were observed as in the study by Ricciardi Coppedê *et al*. In contrast, Dibart *et al*. analyzed the morphology of the surfaces, the internal surface of the implants and the external surface of the prosthetic abutments, where friction marks and scrapes oriented vertically in the direction of the long axis of the implant were identified. Significant grooves in the tapered portion of the abutments and deformations of irregularities with dent aspect were also observed in this study (Ricciardi Coppedê *et al*.). Therefore, further studies may standardize the amount of force applied to the implant/abutment without any damage to its structures and in the final retention of the component are suggested.

Lastly, further in situ studies confirming the clinical relevance of our findings are necessary, since in vitro studies may not faithfully represent this reality. Further studies should also be conducted to evaluate the influence of mastication on the removal force of the abutments considering its biomechanical complexity (Ricciardi Coppedê *et al*.).

No significant statistical difference was observed in change in final retention among the nine SIRs evaluated in the ten abutment/implant sets. The force required for the abutment decoupling increased as the sequences were performed on all ten abutment/implant sets. No significant deformations, fractures, or cracks in the heads of the implants were observed in the SEM analysis. Only small contact marks in the direction of the abutment attachment were seen.

DA SILVA, J. M. Evaluación de la resistencia a la tracción después de la inserción y extracción de pilares en implantes de cono de fricción Morse. *Int. J. Odontostomatol.,15(2)*:356-362, 2021.

RESUMEN: Este estudio tuvo como objetivo evaluar los posibles cambios en la retención final después de nueve secuencias de inserción y extracción (SIR) de un sistema de implante / pilar de cono de fricción Morse, evaluando la fuerza necesaria para disociar este conjunto entre secuencias y verificando posibles deformaciones en las cabezas de los implantes. Se acoplaron diez implantes, de 13 mm de largo y 3,3 mm de diámetro, a una máquina universal de ensayos mecánicos. Se conectaron a los implantes en paralelo al eje largo diez pilares antirrotacionales, de 13 mm de largo y 3,5 mm de diámetro, mediante un instrumento llamado beat-connection, y se sometieron a pruebas de tracción y análisis SEM. Los resultados se analizaron mediante la prueba de Kruskal-Wallis con la prueba posterior de Dunn, y el nivel de significancia se estableció en 5 %. No hubo diferencias estadísticamente significativas en la retención final entre los nueve SIR evaluados. La fuerza necesaria para desacoplar el pilar del implante aumentó a medida que se realizaban SIR en los diez implantes, y se observó un aumento del 29,03 % en el noveno SIR en comparación con el primer SIR. Después del análisis SEM, no se observaron deformaciones, fracturas o grietas significativas en las cabezas de los implantes.

PALABRAS CLAVE: Resistencia a la tracción, Implante dental, Fricción, Diseño de implante-pilar dental, Odontología.

REFERENCES

Aguirrebeitia, J.; Abasolo, M.; Vallejo, J. & Ansola, R. Dental implants with conical implant-abutment interface: influence of the conical angle difference on the mechanical behavior of the implant. *Int. J. Oral Maxillofac. Implants, 28(2)*:e72-82, 2013.

Aguirrebeitia, J.; Müftü, S.; Abasolo, M. & Vallejo, J. Experimental study of the removal force in tapered implant-abutment interfaces: A pilot study. *J. Prosthet. Dent., 111(4)*:293-300, 2014.

Bozkaya, D. & Müftü, S. Mechanics of the tapered interference fit in dental implants. *J. Biomech., 36(11)*:1649-58, 2003.

Dibart, S.; Warbington, M.; Su, M. F. & Skobe, Z. In vitro evaluation of the implant-abutment bacterial seal: the locking taper system. *Int. J. Oral Maxillofac. Implants, 20(5)*:732-7, 2005.

Feitosa, P. C: P.; de Lima, A. P. B.; Silva-Concílio, L. R.; Brandt, W. C. & Claro-Neves, A. C. Stability of external and internal implant connections after a fatigue test. *Eur. J. Dent., 7(3)*:267-71, 2013.

Mangano, C.; Mangano, F.; Piattelli, A.; Iezzi, G.; Mangano, A. & La Colla, L. Prospective clinical evaluation of 1920 Morse taper connection implants: results after 4 years of functional loading. *Clin. Oral Implants Res., 20(3)*:254-61, 2009.

Moon, S. J.; Kim, H. J.; Son, M. K. & Chung, C. H. Sinking and fit of abutment of locking taper implant system. *J. Adv. Prosthodont., 1(2)*:97-101, 2009.

Rabelo, S. C.; Omonte, S. V.; Vieira, S. P.; Jansen, W. C. & Seraidarian, P. I. Morse taper internal connection implants: would abutment reseating influence retention? *Braz. J. Oral Sci., 14(3)*:209-13, 2015.

Rack, A.; Rack, T.; Stiller, M.; Riesemeier, H.; Zabler, S. & Nelson, K. In vitro synchrotron-based radiography of micro-gap formation at the implant–abutment interface of two-piece dental implants. *J. Synchrotron Radiat., 17(Pt. 2)*:289-94, 2010.

Ricciardi Coppedê, A.; de Mattos, M. G. C.; Rodrigues, R. C. S. & Ribeiro, R. F. Effect of repeated torque/mechanical loading cycles on two different abutment types in implants with internal tapered connections: an in vitro study. *Clin. Oral Implants Res., 20(6)*:624-32, 2009.

Schmitt, C. M.; Nogueira-Filho, G.; Tenenbaum, H. C.; Lai, J. Y.; Brito, C.; Döring, H. & Nonhoff, J. Performance of conical abutment (Morse Taper) connection implants: a systematic review. *J. Biomed. Mater. Res. A, 102(2)*:552-74, 2014.

Steiner, M.; Mitsias, M. E.; Ludwig, K. & Kern, M. *In vitro* evaluation of a mechanical testing chewing simulator. *Dent. Mater., 25(4)*:494-9, 2009.

Zielak, J. C.; Rorbacker, M.; Gomes, R.; Yamashita, C.; Gonzaga, C. C. & Giovanni, A. F. In vitro evaluation of the removal force of abutments in frictional dental implants. *J. Oral Implantol., 37(5)*:519-23, 2011.

Zipprich, H.; Weigl, P.; Ratka, C.; Lange, B. & Lauer, H. C. The micromechanical behavior of implant-abutment connections under a dynamic load protocol. *Clin. Implant Dent. Relat. Res., 20(5)*:814-23, 2018.

Corresponding author:
Jader Moreira da Silva
University Center of State of Pará
School of Dentistry
Nine of January street; nº 927
neighborhood: São Braz
ZIP CODE: 66037000
Belém, PA
BRAZIL

E-mail: moreirajader@hotmail.com

https://orcid.org/0000-0003-2667-9739.