Athough the success of dental implants is closely related to osseointegration, the mechanical complications responsible for loosening the screws that fix the prosthetic abutments remain as common faults, resulting in the need for maintenance and repair.1–6 Therefore, understanding the mechanical functioning of prosthetic connections is of great importance for specifying treatment and introducing new technologies that can optimize the clinical results of implants.4,7,8

Since the most common fixation method of prosthetic components is using screws, the stability of the implant-abutment connection depends on preload achieved by torque application on abutment screws. Thus, manufacturers have worked to improve the design of connections to maximize the stability of the implant-abutment junction.6 When occlusal forces exceed the preload, mechanical problems such as loosening of the screws or fractures may occur.3,4,6 In order to overcome these inherent disadvantages to external and internal hexagonal implants, the use of tapered internal connections with a positive locking mechanism in the implant-abutment junction seems to improve the biomechanical performance.5,9–11 Although it was speculated in the literature that cyclic loads increase the positive locking of Morse taper connection implants, there is no current study demonstrating this effect. The connection resistance improvement comes from better adjustment between the components, which can lead to a reduction in the prosthetic screw torque loss since the screw loosening seems to be a result of the compensation of the high stress suffered by the system when it absorbs the overload.3,4

When Morse taper implants were introduced in the dental market, they were placed with an assembly that has been eliminated by adding an indexing system inside the cone. These changes make the prosthetic system more versatile and have been a trend among manufacturers.4,12 With the indexed implant, it eliminates the need to work with intermediaries. From the manufacturers’ point of view, this would increase the

Do Oblique Cyclic Loads Influence the Tensile Strength of Different Morse Taper Connection Abutments?

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Purpose: The purpose of this in vitro study was to evaluate the behavior of abutments attached to Morse taper connection implants, with and without internal index, against oblique cyclic loads. Materials and Methods: Twenty test pieces composed of abutments connected to Morse taper implants solely by friction action were subdivided into two groups (n = 10): group NI (no index) and group I (index). The test units were submitted to tensile tests, before and after cycling loads. Paired t tests were used for intragroup data at different times, and independent t tests were used for the comparisons between the groups. Results: There was a statistically significant difference in both the groups when the precycling and postcycling tensile values were compared. In the comparison between the no index and index groups, there was no statistically significant difference in precycling and postcycling tests. Conclusion: Within the limitations of this in vitro study, it can be concluded that the cyclic loads increased the tensile strength of abutments on Morse taper implants regardless of the index presence. On the other hand, the presence of an index did not significantly alter the values of tensile tests, before and after cyclic loads. Int J Oral Maxillofac Implants 2019;34:1047–1052. doi: 10.11607/jomi.7506

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acceptance of the use of this connection among dentists. However, these changes can affect the behavior of the system\textsuperscript{6,6,12} since it changes the original design of the cone, reducing the contact area between the implant and the abutment, which supposedly reduces the settling effect between the different parts. Therefore, it is to be expected that this modification would reduce the preload obtained by the conical effect.

The aim of this study was to demonstrate the behavior of the Morse taper prosthetic connection in dental implants with and without an internal index, against oblique cyclic loads that simulate the masticatory force. The following hypotheses were tested: (1) the application of cyclic loads influences the tensile strength of the Morse taper connection abutment; and (2) the presence of an internal index in Morse taper implants influences the prosthetic abutment tensile strength.

**MATERIALS AND METHODS**

In this investigation, 20 Morse taper connection implants, 3.5 mm \( \times \) 11.0 mm with 11.5-degree internal angle conical connection, were divided into two groups according to implants used: 10 of them had implants with an internal conical connection without an index and with their assembly (Titamax CM cortical, Neodent; Fig 1a) (group NI), and the other 10 had implants with an internal hexagonal index (Fig 1b) and used a surgical insertion technology with an internal torque (Titamax EX CM, Neodent) (group I). Also, 20 abutments measuring 4.5 mm \( \times \) 6.0 mm \( \times \) 2.5 mm (CM universal two-piece abutment, Neodent) were chosen along with 20 standard wax-up copings (Standard cylinder, Neodent) to be cast with a NiCr alloy to form the test unit.

All procedures involving the sample assembly and the cycling tests were performed according to ISO 14801: 2007 for dynamic endosteal dental implant fatigue testing.\textsuperscript{13}

Implants were placed in cylindrical acetal resin blocks (Nitacetal, Nitaplast) with 22.0 mm length \( \times \) 15.0 mm diameter and an elastic modulus similar to human bone. Perforations were made following the sequence of drills recommended by the manufacturer, with a surgical motor (Implantmed, W&H) attached to a parallelizer (1000N, Bio Art) in order to standardize the insertion perforations in the vertical position and in the center of the acetal resin block. Implants were placed using a surgical torque wrench (Neodent) with a 40 Ncm maximum controlled torque. The torque wrench was calibrated before the experiment in accordance with ISO 6789: 2003 and BSEN26789/1994. Only 9 mm of the total length of each implant was incorporated into the resin, leaving 2 mm of implant surface uncovered to simulate a bone loss condition.

In order to secure the joint of the abutments to implants solely by the friction of the parts, the screws were removed with an aluminum oxide disk (Ninja Red, Talmax), simulating a press-fit connection.\textsuperscript{14} Thus, the abutments were fixed to the implants with an axial force of 13.51 kgf, corresponding to the preload obtained by tightening the screw (a torque of 15 Ncm recommended by the manufacturer). This was done on a universal test machine (KS005, KRATOS) with a 100-kg load cell. The value of 13.51 kgf is justified because when a universal two-piece abutment is inserted in the Morse taper implants, the tightening torque required to reproduce the force moment (M) generated by the thread friction and junction friction is calculated using the following equation:\textsuperscript{15}

\[ M_{\text{tightening}} = M_{\text{thread friction}} + M_{\text{joint friction}} \]

In the present study, a simplified engineering formula was used to determine the axial preload (Fv) of the moment tightening:\textsuperscript{14}

\[ M_{\text{tightening}} = F_v \times (0.159 \times P + \mu \times 0.577 \times D_2) + F_v \times D_c \times \mu \times 1 / \cos \alpha \]

In the above formula, the following values were considered, according to the manufacturer’s data, to the cited parameters: \( P \) (screw pitch) = 0.35 mm; \( D_2 \) (mid-diameter of the flank of the screw thread) = 1.573 mm; \( D_c \) (mid-diameter of the cone) = 2.2 mm; \( \alpha \) (angle between the implant axis and the surface orthogonal to the cone) = 84.25 degrees; \( \cos \alpha = 0.100188 \); and \( \mu \) (friction coefficient) = 0.5.
Crown patterns were made on wax-up coping and cast with a Cr-Co alloy. Crowns obtained were cemented to the abutments with zinc phosphate cement (LS Cement, Vigodent) to form the test units (Figs 2a and 2b).

Tensile Strength Test: Precycling
After applying the axial preload force, a traction device was attached to the crowns, and the tensile test was performed with a universal testing machine (K 500S, Kratos) (Fig 3). The assay was conducted with a 10-kgf load cell at a speed of 0.5 mm/min until the separation of the abutment connected to the implant. The tensile strength values were obtained in Newtons.

Abutments were again connected to the implants, applying the axial load referring to the preload, which were then subjected to mechanical cycling.

Mechanical Cycling and Postcycling Tensile Strength Test
A mechanical cycling test was then performed in a thermomechanical cycling machine (ER 37000, Erios), according to the ISO standard. For this experiment, $1 \times 10^6$ cycles were performed at 5 Hz with an angulation of 30 degrees in relation to the axis of the implant. A compressive load of 150 N was applied in order to simulate the masticatory load of 5 years. This experiment was followed by another or a second crown traction test, which measured the postcycling tensile strength, as previously described.

Statistical Analysis
Data were submitted to the Shapiro-Wilk normality test ($P = .05$) and the paired t test in order to compare the traction force required to remove the abutments before and after cycling between groups NI and I. In relation to the presence of index, the Student t test for independent samples was used to compare the groups. All data were tabulated and submitted to statistical analysis using the SigmaPlot 11.0 software (Systat).

RESULTS
Figure 4 shows the relation of the abutment’s tensile strength in the different groups and test phases correlated with the $P$ values.

The mean tensile strength before and after cycling presented a statistically significant difference for both groups tested. However, in the comparison of the NI implant group with the I group, the mean values of the traction force of the abutments were not statistically different, independent of the evaluation moment (precycling and postcycling).
DISCUSSION

The results of this investigation indicate that a greater force is required to remove the abutment from the implant after cycling load application. Thus, the hypothesis that the oblique cyclic loads influence the traction strength of tested Morse taper connection abutments was accepted. Data suggested that cyclic loads produced a positive influence on the settlement effect between conical connection implants and abutments, a clinical feature that could lead to a reduction of the percentage of loose screws, when using this type of system, compared with indexed hexagon systems.

Pardal-Peláez and Montero concluded in their systematic review that internal connection is more resistant to cyclic fatigue when analyzing the screw loosening. According to these authors, screw loosening is associated with the occurrence of micromovements at the implant-abutment interface. However, the cause-effect relation involving micromovement, abutment screw loosening, implant-abutment imbrication, and cyclic loading action on Morse taper connections is poorly established in the literature. Thus, from the finding of the present study, it can be assumed that cyclic loads would reduce the abutment micromovement on Morse taper connection implants, agreeing with the conclusions of Pardal-Peláez and Montero in their review.

Implant-abutment joint stability may be affected by other factors. Tightening and removal torques have been used to determine the stability of this joint, with the removal torque generally being smaller than the tightening torque, maintaining constant parameters such as friction, geometric properties of the screw, cone angle, and elastic properties of the materials.

Kim et al, in their study on implant-abutment stability, found that the seating of pieces was better after applying a tightening torque. Conversely, Ricciardi Coppê et al verified a reduction in the removal torque of the abutment screw after the insertion/removal cycles in Morse taper abutments. Seol et al found a reduction in the torque after cyclic loading on the external and internal connection implants. De Oliveira Silva et al found that different types of Morse taper connections tested did not have a significant influence on the removal torque after thermomechanical cycling. Ricomini Filho et al reported that the group tested with a Morse taper implant and a universal two-piece abutment presented higher removal torque values compared with the preload, after thermocycling and mechanical fatigue.

Most authors studying the joint implant-abutment have performed their analysis by measuring the force used to unscrew the abutment screw, either after tightening removal torque, after retightening torque, or after simple initial torque. However, both the tightening and retightening, as well as the mechanical cycling, involve an additional insertion force in the axial direction, which can influence the mechanical fit of the parts. The maintenance of the screw in those studies, using the torque parameter before and after the tensile test execution, can cause changes in the results since the force necessary to release the screw for the test execution may reduce the press fit effect gained through cyclic fatigue. Thus, such studies tested the bolt action rather than the conical connection itself.

Therefore, it would not be possible to determine the positive effect of the cyclic loads on the Morse taper connections by only evaluating the torque required to unscrew the abutment.

Another question is: how would the cone imbrication affect the force necessary to unscrew abutments? Would it be correct to assume that the increase of settling effect would reduce the force to unscrew a two-piece abutment, as seen in previous studies? The mechanical seating in single-body abutments only happens once the preload torque is applied, due to the rotation that accompanies the screwing inside the implant. In turn, in two-piece abutments, the fixing screw only influences the vertical movement of the insertion of the abutments. Thus, these abutments are more susceptible to functional and parafunctional occlusal loads and, therefore, are better suited to evaluate the “Morse effect” versus cyclic loads. In the present study, abutments were held in place just by the conical connection settlement to evaluate this effect, removing the fixation screws prior to the mechanical tests. Thus, only the settlement was evaluated, without the influence of the unscrewing action. In this case, the screw presence could mask the results on the settlement of the cones during pull-out movement. The removal of the screw allowed the evaluation to be carried out under similar conditions to the mouth, where occlusal loads are transferred primarily to the implant-abutment interface, in case of two-piece abutments connected to implants with a conical internal connection, and not directly to the screws. Removal of the screw justifies the main reason for this work. If the components were screwed, it would not have been possible to pull the components to perform the measurement, and a previous release of the components, by an unscrew action, would cover the true result. For this reason, two-piece abutments that could be pulled out were used to allow the careful evaluation of the cyclic load effect on the fit of the parts.

Although the presence of an index in Morse taper implant does not reduce the fracture strength of the implant and the abutment, the hypothesis that the introduction of an anti-rotational device, that possibly reduces the contact area between the implant and abutment, influences the abutment tensile strength.
was not accepted. De Oliveira Silva et al4 emphasized that the presence of an internal hexagonal index in the abutment significantly reduced the force required to dislodge it from the implant. However, in their study, the authors tested different abutments on the same Morse taper indexed implant. In this case, the influence of the cycling may have been masked by the screw presence and the unscrewing action when the test results were obtained.

The results of the present study showed that the decrease in the tensile values of the index group was not significant. Among all the parameters related to screw loosening, the height of the contact between the parts seems to be the one that most affects the removal strength of the Morse taper implants.2,7,25 This may explain the results found since cone height was not modified by the introduction of the anti-rotational device. In addition, the tensile test performed to obtain those values was not preceded by the removal torque action. However, among the studies reviewed, only a few tested the strength of the implant-abutment settling on the tapered implants through the pull-out test of the prosthetic abutment, as performed in this study.4,17,22

Clinical significance of the first hypothesis of this study leads to an expectation that the use of Morse taper prosthetic connection implants could minimize the intercurrences related to the screw loosening since the embedment of components would reduce the transfer of loads to the screws. Regarding the second hypothesis, since the presence of an index in Morse taper connection implants did not influence the traction force needed to remove the abutments, the use of this type of connection could facilitate the correct positioning to reduce the chances of a mistake in the result of treatment.

Given the limitations of in vitro studies, the simulated conditions in this experiment were designed to approximate the clinical situation. Therefore, in this study, cemented crowns in the abutments and mechanical fatigue tests were used to simulate the masticatory function in the mouth, but due to the complexity of mastication biomechanics, this study has limitations that must be considered when interpreting the results.

The fact that the same test pieces were used for all test phases allowed the authors of the present study to carry out paired statistical analysis, which would not be possible if the test pieces were different. It is also worth mentioning about this methodology that connecting the abutment to the implant, including withdrawing and then reconnecting it, is a clinically acceptable situation and compatible with the clinical management routine of components.

Additional studies comparing internal conical connections with different angulations, using a protocol to evaluate the settling effect without the interference of the torque in abutment screw, are suggested.

CONCLUSIONS

Based on the hypotheses proposed in the study, it was concluded that: the application of oblique cyclic loads influenced the tensile strength of abutments since its removal force has increased; and the incorporation of an internal index in the Morse taper implants did not influence abutment tensile strength, maintaining the mechanical settling of the abutment.

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REFERENCES