An in vitro study comparing the stability of various prosthetic screws subjected to cyclic loading in implant prosthodontics

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ABSTRACT
A comparison is going to be made between the loss of preload on a 7-mm distal cantilever in two different connection systems using an all-on-four prosthetic model when there is no loading and after a set number of cyclic loadings have been performed on the cantilever. Methods: An edentulous mandible was rehabilitated using an all-on-four technique with two different types of abutment systems (MUA and OT-Bridge) in order to support hybrid prosthesis. Two equal models of an edentulous mandible were used. Using a mechanical torque gauge, initial torque values of the prosthetic fixing screw were registered after ten minutes of initial screw tightening, after 400,000 repeated loadings, and after the initial screw tightening. Differences between the initial and final torque values were reported for each anchoring system, and the results of the comparison between the two systems were presented. After 400,000 cyclic loadings, the results showed that there was no statistically significant difference in the loss of preload between the MUA system and the OT-Bridge system. However, in the MUA system, a statistically significant difference was found between the anterior and posterior implant screws. Only for the MUA system was a statistically significant difference in preload loss found when comparing the initial screw torque to that measured after 10 minutes from the tightening in the absence of cyclic loadings. This was the case. Within the scope of the present investigation, the findings suggest that the MUA and OT-Bridge may be considered reliable prosthetic anchoring systems that are able to withstand repeated cyclic occlusal loads on the distal cantilever in an all-on-four rehabilitation model without experiencing any significant loss of preload in screw tightening.
Keywords: preload loss; conical abutment screw; multi-unit-abutment; OT-Bridge; prosthetic connection; implant-supported prosthesis; loosening torque; tightening torque.

INTRODUCTION

For the rehabilitation of totally edentulous patients over the past few decades, the use of screw-retained prostheses on implants has become increasingly common [1,2,3]. On the basis of the presence of bone atrophy, the pneumatization of the maxillary sinus, the quantity of bone that is available, and the location of the inferior alveolar nerve and mental foramina, multiple solutions for the rehabilitation of the upper and lower jaw have been proposed and accepted in the body of scientific literature [4,5,6,7]. The All-On-Four technique, which was initially proposed by Malo et al. [8] for the rehabilitation of completely edentulous mandibles, is currently used by a number of clinicians [9,10,11] in order to achieve the correct masticatory and speech functions, as well as an optimal prosthetic support, and to re-establish an acceptable situation for the patient [12]. In this kind of implant-supported rehabilitation, intermediate components are used between the implant fixtures and the prosthetic framework in order to correct implant misalignment and achieve a passive fit of the framework. This is done in order to make the framework as comfortable as possible for the patient. One of the most common anchoring systems that is utilized for this procedure is known as the Multi-Unit-Abutment (MUA). This system is made up of components that are either straight or angulated, and they range in height. These components are used to move the implant's internal connection to a conical external connection. Even in the case of implant disparallelism, a passive prosthetic fit can be achieved by doing things in this manner. In addition, the occlusal stress is transferred from the implant screw to the multi-unit abutment screw, which is smaller than the first screw and has the potential to become the weak point in the event that there are complications with the prosthetic.

An alternative to the MUA system is the OT-Bridge® system, which was just recently released onto the dental market and is located in Rhein 83, Bologna, Italy. The OT-Bridge system is made up of a low profile attachment for overdentures known as the OT-Equator, a sub-equatorial component known as an interchangeable undercut acetal ring known as the Seeger ring, and a cylindrical titanium abutment with a cavity at the retentive extremity that is designed for the insertion of the acetal ring. A safe and effective elastic retention system of the abutment is offered by the Seeger ring in this manner. This safeguards the abutment against the possibility of the prosthesis unscrewing. The chipping of the prosthesis, the fracture of the abutment, and the fracture and loosening of the abutment/implant screw are the three mechanical complications in implant-supported prostheses that occur the most frequently [13,14,15,16]. This final complication is always preceded by a reduction in its preload [17,18,19,20]. Preload is defined as the axial force that is generated between the threads of the screw and the internal part of the implant in the long axis direction when the screw is being tightened. This last complication is always preceded by a reduction in its preload. Several factors, including screw geometry, material properties—particularly stiffness—surface texture and condition of mating surfaces, degree of lubrication, rate of tightening, integrity of joint, prosthetic misfit, and so on all play a role in screw loosening [17]. The metal alloy composition of the screw and the abutment is an important factor that influences the stability of the joint system in terms of preload absorption [18,19]. This is because the metal alloy composition of the screw and the abutment defines the entity of the friction that occurs during the mating of the threads. Additionally, the form of the abutment, whether it was machined or cast, as well as the surface coating and implant connection systems may all play significant roles in relation to this phenomenon.

To the best of our knowledge, there are currently no studies in the literature that compare the MUA and the OT-bridge in terms of the number of prosthodontic complications that can arise from either procedure. In this in vitro study, the all-on-four prosthetic model was used to compare the loss of preload in MUA and OT-Bridge connection systems with and without cyclic loading on a 7-mm distal cantilever.

MATERIALS AND METHODS

For this type of in vitro research, approval from the ethics committee was not necessary.

MODELS REALIZATION

A single silicon oral impression of an edentulous mandible model that had been rehabilitated with four implants in the position of canines and second premolars in accordance with the "all-on-four" concept [8] was used to create two reference models that represented the patients. These models were obtained from the silicon oral impression. The axes of the implants in the canine position were orthogonal to the occlusal plan, and the axes of the implants in the second premolar were angulated distally for 30 degrees when they were placed. Each implant was placed in accordance with a predetermined angulation. The models were fabricated with epoxide resin (Trias Chem Srl, Parma, Italy), which was loaded at 300%. This was done in order to improve the models' mechanical properties and to ensure that they could withstand the chewing loading without undergoing any modifications. This was done in order to simulate the mandibular bone. We used four implant analogues with an internal hexagonal connection. The implant analogues measured 3.5 mm by 10 mm and were manufactured by Nobel Biocare in Kloten, Switzerland. In order to secure the model to the machine and enable dynamometric control of the loads, a hole with the appropriate calibration was drilled in the model's center.

In the model A, the MUA (Nobel Biocare) screws were tightened to a value of 35 N/cm on the anterior straight implant analogues, and they were tightened to a value of 15 N/cm on the posterior implant analogues that were tilted. In the model B, each implant analogue was fastened with four OT-equators at a torque of 25 N/cm. On each model, a milled cobalt-chrome framework for hybrid prosthesis was created using the same file system. In the framework for Model A, an internal conical attachment complete with a connection screw hole was realized, while in Model B, an extra-grade abutment was used. In order to obtain a distal cantilever 7 mm long, between the central fossa of these elements and the last implant according to the most predictable protocols in the literature [21,22], the first molars were located distally to the posterior implant platform. This allowed for the creation of a cantilever distal to the posterior implant platform.

CANTILEVER AT THE DISTAL END HAVE ITS LOADING CYCLES SIMULATED

The connecting screws on implant analogues were tightened using a torque-controlled dynamometric micro motor called Implantmed Plus (W&H, Brusaporto—BG, Italy). This was done in accordance with the manufacturer's indications. The following list is comprised of torque values: On Model A, the angulated posterior implants have a force of 15 N/cm, while the straight anterior implants have a force of 35 N/cm. Model B has a force of 25 N/cm. After waiting 10 minutes after the initial torque application, the implant screws were then retightened in order to compensate for the settling effect, as described by Winkler et al. [18]. After waiting for 10 minutes, the same machine was used to determine the screw insertion torque. Loading cycles on a 7-mm distal cantilever were simulated using MTS-Acumen 1 (MTS Systems S.R.L, Turin, Italy), an electrodynamic testing machine that acted as a presser dynamometer and on which was mounted a metal bracket ending with two spherical geometrical tips that were positioned on the central fossa of the first molars of the model. This machine was manufactured in Italy by MTS Systems S.

The central fossa of the first molars was subjected to a variable ascending and descending force that ranged from 40 to 400 N and was repeated at a rate of 1.6 Hz for 400,000 times. This force was applied in a direction that was perpendicular to the occlusal plane and parallel

to the axis of the anterior implant analogues. The values of the forces that were applied as well as the number of cycles were determined by following the protocols outlined in the relevant body of literature [8,23] and taking into consideration an ideal number of cycles for one-year cyclic loading [24,25,26]. After cyclic loading, the loosening torque was measured, and each connecting screw was replaced with a brand new one. Additionally, the acetal ring was replaced in the OT-Bridge system. For each system, a total of five tests were carried out. The MTS-Acumen 1® software performed real-time checks to ensure that there were no errors or collateral movements during the loading cycles on the cantilevers. The software also ensured that there were no inaccurate loading cycles. The literature [17] indicates that the difference between the initial torque and the torque measured while loosening the screw was assumed to be the loss of preload. This assumption was based on the fact that the initial torque was higher. The torque was determined by employing the Implantmed Plus (W&H) torque-controlled dynamometric micro motor for the measurement.
Analysis of Variance (ANOVA) Was Used to Compare the Preload Loss between the Two Systems in the Absence of Load and after Cyclic Loading The preload loss was compared between the two systems using the analysis of variance (ANOVA). In addition, an ANOVA was carried out to evaluate the difference in preload loss between anterior and posterior implants in both systems. The assumption that there was no difference in preload loss served as the null hypothesis. The level of significance was determined to be 0.05. In order to conduct statistical analysis, the SPSS Statistics software version 24 for Mac was utilized.

RESULTS

Table 1 compiles the results of a synthesis of the percentages of preload loss that occurred throughout the five tests conducted on Multi-Unit-Abutment and OT-Bridge.

Table 1 shows the results, broken down by % preload loss over the course of 5 tests.

		Multi-Unit-Abutment				**OT-Bridge**			
%Preloadlossamongtests	1°test	31	36	42	49	47	33	42	59
	2°test	37	42.1	44	45	49	42	42	43
	3°test	42	22.4	41	31	41	43	43	45
	4°test	37	39.6	28	49	55	31	41	35
	5°test	39	32.1	32	43	42	35	57	33

On the Model A, the loss of preload was calculated to be 38% overall mean. The anterior implants reported a loss of preload of 38%, while the posterior elements reported a loss of preload of 41%. As a result of the fact that this difference was statistically significant (p=0.01), the null hypothesis was disproved (Table 2).

Table 2: A comparison of the absolute loss in preload experienced by anterior and posteriorly placed MUAs.

		33-43	35-45
N/cm2PreloadlossinMultiUnitAbutment	1°test	13	8.7
	2°test	13.2	8.4
	3°test	12.8	9.1
	4°test	12.1	8.2
	5°test	11.9	8.7

The overall mean loss of preload without cyclic loading was 32%, while the mean loss of preload after cyclic loading was 38% across all five tests, with no statistically significant difference between the two (p = 0.22). The overall mean loss of preload that was measured in the Model B connecting screws was 44.1 %. When compared to the posterior elements, the connecting screws on the anterior implant analogues experienced a preload loss of 43.7%, whereas the posterior elements experienced a preload loss of 44.2%. The fact that there is no statistically significant difference (p = 0.33) when comparing the values that were measured using the two different sets of screws led to the conclusion that the null hypothesis should be accepted. Following the application of 400,000 chewing cycles, the average loss of preload on the five tests it was 42%, with the difference not being statistically significant (p = 0.51). The overall mean loss of preload was 42% when there was no cyclic load present. When the two models were compared, it was discovered that there was no statistically significant difference in the mean loss of preload after cyclic loading (p = 0.31).

DISCUSSION

Loss of preload is one of the most common complications that can arise when working with implant-supported prosthodontics [27,28,29]. This complication falls under the larger category of mechanical complications. It always comes before the screw becoming loose, which occurs with an incidence of 5.3% after one year of loading and between 5.8% and 12.7% after 5 years [16,17,29,30,31]. According to the research that has been done, the loss of preload can be caused by a number of different factors [17,27,28]. These factors include the kind of material that was used to make the abutment and the connecting screw, the geometry of the connection between the fixture and the implant, the kind of prosthesis that was used, the shape of the abutment screw head, and the method that was used to screw the implant in [18,19,20,24]. All of these factors, with the exception of the metal alloy composition of the screw and the abutment of the two joint systems, were controlled in the study that is being discussed here. In particular, the abutment and connecting screw in the MUA system that was utilized are both made of grade 4 commercially pure titanium. In contrast, the OT-Bridge system features a titanium nitride coating the low-profile attachment along with an anodized titanium anchoring screw. It is possible that this is the reason why the MUA system was the only one in which a difference was found between the initial torque value and the torque value registered after 10 minutes of being unloaded. Because of the high Young's modulus and the low elastic recovery of grade 4 commercially pure titanium, there is probably a significant amount of friction that occurs during the mating of the threads [18,19], which leads to a reduction in preload. Therefore, we are able to postulate that the alloy make-up of the OT-Bridge system prevents this scenario from occurring. Gold-Tite screws better adapt the mating counterpart of the implant bore, thanks to the ductility and malleability properties of this material [18,19]. This is evidenced by the fact that some studies published in the medical literature came to the conclusion that the material of the connecting screw plays a significant role in the loss of preload. The fact that the two connection systems did not show statistically significant differences in terms of the loss of preload following the simulation of 400,000 loadings on the distal cantilever, which is approximately equivalent to one year of cyclic loadingis an interesting finding that came out of this research. [24,25,26] This was one of the findings that stood out to the researchers as being particularly noteworthy. In Model A (MUA system), the application of occlusal forces on the distal areas, perpendicular to the occlusal plane and parallel to the long axis of the anterior implants, produces a statistically significant difference between the connecting screws on anterior and posterior implants. This difference is only observed when the occlusal forces are applied perpendicular to the occlusal plane and parallel to the long axis of the anterior implants. The lack of this evidence in the OT-Bridge system may be attributable to the existence of the acetal ring, which offers a snap retention in contrast to the upward traction force. Based on these findings, it appears that both MUA and OT-Bridge are trustworthy prosthetic anchoring systems, even when subjected to unfavourable conditions such as the application of occlusal forces on a distal cantilever measuring 7 mm. The presence of the acetal ring on the OT-Bridge system, which stabilizes the prosthetic structure in the event that the screws become loose, is an important distinction for the biomechanical comparison of these two systems. In other studies, it would be important to evaluate the significance of the "snap" retention on the extra-grade abutment of the prosthesis once the correct tightening of the screw has been lost. Additionally, it would be important to assess the behavior of this acetal ring while all of the masticatory functions are being performed.

The fact that the research was conducted in vitro is the primary factor that contributes to the limitations of this work. In order to evaluate the two joint systems, only one significant stress condition was used, which consisted of performing compressive cycles on a 7-mm distal cantilever. Other loading conditions that occur in the patient's mouth were not investigated, but they do exist there.

Because the effects of saliva and food on the longevity of the MUA system are well-documented in the research literature, very little or no information is available regarding the OT-Bridge system. However, the OT-equator can also be used for the rehabilitation of overdentures, and this application has been shown to be successful in the mouth of the patient [14]. Additionally, the temperature may have an effect on the preload loss; however, we do not evaluate this factor in this study. Even though an epoxide resin model was loaded at 300% in order to enhance its mechanical properties to mimic mandibular bone, the models still only simulate the strength and plasticity of alveolar bones to a limited degree. This is the case despite the fact that the models used an epoxide resin model. In addition, there is a possibility that faulty fabrication occurred during the construction of the two models.

CONCLUSION

Within the confines of this in-vitro study, it is possible to draw the conclusion that MUA and OT-Bridge may be considered to be reliable prosthetic anchoring systems that are able to tolerate cyclic occlusal loads on distal cantilever in all-on-four rehabilitation without any significant loss of preload in screw tightening. This is the conclusion that can be drawn from the study's limitations. To demonstrate the clinical reliability of this new anchoring system in comparison to the established gold standard, however, additional in-vitro and in-vivo studies with larger samples and a variety of conditions, as well as clinical trials with extended follow-up periods, are required.

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