Screw loosening of different UCLA-type abutments after mechanical cycling

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Abstract

Aim: To evaluate the loss of applied torque (detorque) values in cast and pre-machined abutments for external hex abutment/implant interface of single implant-supported prostheses subjected to mechanical cycling.

Methods: Ten metal crowns were fabricated using two types of UCLA abutments: cast and pre-machined with metal base in NiCrTi alloy and tightened to regular external hex implants with a titanium alloy screw, with an insertion torque of 32 N.cm, measured with a digital torque gauge. Samples were embedded with autopolymerizing acrylic resin in a stainless steel cylindrical matrix, and positioned in an electromechanical machine. Dynamic oblique loading of 120 N was applied during 5 x 10⁵ cycles. Then, each sample was removed from the resin and detorque values were measured using the same digital torque gauge. The difference of the initial (torque) and final (detorque) measurement was registered and the results were expressed as percentage of initial torque. The results of torque loss were expressed as percentage of the initial torque and subjected to statistical analysis by the Student’s t-test (p<0.05) for comparisons between the test groups.

Results: Statistical analysis demonstrated that mechanical cycling reduced the torque of abutments without significant difference between cast or pre-machined UCLA abutments (p=0.908).

Conclusions: Within the limitations of this in vitro study, it may be concluded that the mechanical cycling, corresponding to one-year use, reduced the torque of the samples regardless if cast or pre-machined UCLA abutments were used.

Keywords: dental implant, single tooth implant, external hexagon.

Introduction

The mechanical stability of implant-supported fixed restorations may be considered to improve long-term stability and minimize complications. The stability of the connection between different implant parts is important for the success of the rehabilitation, especially for single tooth restorations. Loosening of abutment screws, mainly with the external hex implants, has been a technical problem that occurs in the first two years of use. The stability of the external implant-abutment connection has been improved by altering the screw alloys and their surfaces and applying proper torque values to establish higher initial preloads.

A systematic review compared the complications of screw-retained prosthesis showing that the most frequent complication was related to abutment screw loosening (10-55.5%). The incidence of abutment screw loosening was 4.3% in short-term studies and 10% in long-term studies.

Mechanical factors, such as the implant-abutment fit and the abutment screw preload are involved in the success of implant rehabilitation. The preload loss during the occlusal load favors the misfit of the implant-abutment connection and may cause screw loosening and fracture. Implant biological factors may be
affected due to microgap formation, which can cause peri-
implantitis\(^7\). *In vitro* and clinical studies have demonstrated
the correlation between rotation of the abutment and
prosthetic screw loosening and showed the importance of
reducing to a minimum the implant-abutment misfit in
order to avoid mechanical complications\(^8-9\).

The hexagonal configuration prevents abutment rotation
on the implant surface and provides a stable screw joint
assembly. The amount of freedom between the implant
hexagonal extension and its abutment counterpart has also
been implicated as a factor in screw joint instability. The
applied torque and the masticatory load could generate
micromovements, deforming the implant hexagon. Studies
have indicated a direct correlation between implant-abutment
rotational misfit and screw loosening\(^9-12\).

Preload is the tension on a screw generated when a
torqueing force is applied to the screw head. Occlusal forces
play an important role in screw loosening of hexagonal
connection implants; preload is the only force that resists
to functional occlusal forces in order to maintain the abutment
stability, preventing its separation from the implant. When
the preload is exceeded by the occlusal force, the screw will
loosen\(^13-14\). Several mechanisms can cause screw loosening;
one is the embedment relaxation of mating thread surfaces\(^15\).

Normally, when a screw is tightened, most of the screw
responds elastically (plastic deformation occurs only at spots
of machining microroughness and asperities at thread flanks).
Thus, preload produces a clamping force between the screw
head and its seat. The behavior and life of a screw joint
depends mainly on the magnitude and stability of that
clamping force. In general, the greater the clamped force
(preload), the tighter the clamped joint. However, preload
values should not be too high and should be within the
elastic limit, because retaining screws may yield or break
under repeated functional bite forces. On the other hand, the
preload values should not be too low in order to retain loose
screws under repeated functional forces\(^16\).

Eccentric and compressive forces are generated during
chewing movements and influence the screw retention\(^17,18,19,20\).
The optimal preload values for the implant/abutment screw
joint have not been fully identified and in single tooth
implants this value is critical for screw joint stability\(^21\).

The purpose of this study was to evaluate the loss of
applied torque (detorque) values in cast and pre-machined
(UCLA) type abutments for external hex abutment/implant
interface of single implant-supported prostheses subjected
to mechanical cycling. The null hypothesis was that torque
loss of cast and pre-machined UCLA abutments submitted
to the mechanical cycling is similar.

### Material and methods

Ten metal crowns were fabricated using the two types of
abutments: cast and pre-machined UCLA abutments. All
crowns were fabricated according to a silicone matrix (Silicone
Master; Talmax, Curtiba, PR, Brazil) to present similar
dimensions. The patterns were invested in a rapid cycle, carbon-
free, phosphate-bonded investment (Castorit Super C;
Dentaurum, Ispringen, Germany) and cast using a nickel-
cechromium alloy (Ni-Cr, Verabond II; Aalba Dent Inc.,
Cordelia, CA, USA) to the castable UCLA abutments and
cell chromatium–titanium alloy (Ni-Cr-Ti, Titile Omega;
Talladium, Valencia, CA, USA) to the pre-machined UCLA abutments.

The implants were fixed in a metallic matrix with a
lateral screw in order to prevent implant rotation. The set
implant/metallic matrix was placed at the base of a torque
application device developed in the Department of Dental
Materials and Prosthodontics of the Dental School of Ribeirão
Preto, University of São Paulo. A digital torque meter was
attached to the top of the device (TQ-680; Instrutherm, São
Paulo, SP, Brazil). Initially, the crowns were slightly screwed to
the implants by hand\(^22\). Then the set was placed in a socket at
the device base. This socket allows only rotational movement.
The crowns were torqued to the implants (32 N.cm), according
to manufacturer’s recommendation, using a hexagonal wrench.
After 3 min, the screw was retightened to the same torque to
minimize embedment relaxation\(^23\). The placement torque was
measured by the digital torquemeter with a 0.1 precision.
The sequence is shown on Figure 1 (A-D).

The implant and metal crown were embedded in
autopolymerizing acrylic resin (Jet; Clássico Produtos
Odontológicos Ltda., São Paulo, SP, Brazil) in a stainless steel
cylindrical matrix to standardize the positioning with a 30°
inclination relative to the vertical axis\(^24-26\). An autopolymerizing
acrylic resin was used due to its appropriate elastic modulus
(3GPa) for a bone analog material\(^27\). The replicas were
positioned in an electromechanical machine (MSFM; Elquip,
São Carlos, SP, Brazil) and immersed in distilled water at 37 ± 2
°C. Dynamic oblique loading of 120 N was applied to each
replica during 5 × 10\(^5\) cycles. The load was applied with a
metal cylinder with 4 mm in diameter. The machine was set
to work at a frequency of 101 cycles per minute, simulating
to the human chewing frequency\(^28\) (Fig. 2).

After mechanical loading, each sample was removed from
the resin and returned to the torque application equipment
in the same initial position, and detorque values were measured
with the digital torquemeter. To remove the screw, torque was
applied in a counterclockwise direction, using a hexagonal
wrench attached to the digital torquemeter. The digital torque
was recorded immediately after releasing the screw.

The results of torque loss were expressed as percentage
of the initial torque and subjected to statistical analysis by
Kolmogorov-Smirnov normality test. The Student’s t-test
Fig. 1. (A) Digital torque meter and torque application device. (B) Hexagonal wrench positioned. (C) Crown and wrench before torque application. (D) Application of torque using hexagonal wrench attached to a digital torque meter.

Fig. 2. (A) Electromechanical machine. (B) The load was applied through a metal cylinder with 4 mm in diameter. Samples were immersed in distilled water at 37±2°C.
(p<0.05) was used for comparisons between the groups, using the statistical program SPSS 17.0 (Statistic Package for the Social Science, version 17; SPSS Inc., Chicago, IL, USA).

Results

Table 1 shows the results obtained for the different samples after mechanical cycling. No statistically significant difference was observed (p=0.908) when the two types of UCLA abutments (cast or pre-machined) were compared (Table 2).

Discussion

Since the Branemark system was introduced in the market with an external hexagon to facilitate the implant insertion rather than to provide an antirotation device, several competing systems have used well this design over the years27. Even though there were some failures and other design connections were introduced to overcome these failures, many patients received this design connection. Currently, there is lack of conclusive evidence regarding abutment screw loosening to external hexagon implants, mainly those related to single restorations27. Several factors may cause reduction or loss of preload in single tooth restorations such as casting procedures, superstructure inaccuracy, occlusal morphology and insertion torque, occlusal overload and physical properties of the screw materials28-29.

Kano et al.21 studied the casting effect on torque maintenance by detorque measurements of UCLA-type abutments and observed a detorque mean of 92.3% for the machined titanium abutments, 81.6% for the pre-machined palladium abutments cast with palladium, 86.4% for plastic abutments cast with nickel-chromium, and 84.0% for plastic abutments cast with cobalt-chromium alloy.

In this study, there was no statistically significant difference between cast and pre-machined abutments (p=0.908). The detorque measurement after mechanical cycling revealed a reduction to 13.26±4.32 N.cm (41.4%) for the cast abutment and 13.72±7.36 N.cm (42.9%) for the pre-machined. Despite the use of different abutments, torque reduction was observed for both groups, suggesting changes in the mating surfaces. Any irregularities in the mating surfaces will likely result in preload reduction28. The casting procedures may have contributed to these results since the integrity of screw joint23 and material properties of metal components may be altered during casting21. Therefore, it is important to point out that any irregularity in the mating surfaces should be detected, as changes occur between contacting parts when the screw is tightened because all the metallic contacting surfaces flatten slightly and the microscopic distance between contacting surfaces decreases23.

Other studies also compared plastic, pre-machined and machined abutments and concluded that lower preload has developed for all components subjected to casting15,21,30. This study confirms such results and shows that casting procedures can decrease detorque values even in pre-machined cast abutments, like those used. The reason seems to be the irregularities and roughness of contacting surfaces that may result from the casting process, which causes greater embedment relaxation and consequent preload loss15,30.

The applied torque is distributed to the friction between the screw and the abutment, and between the threads of the screw and the implant, causing loosening. Thus, screw loosening is only avoided if the applied preload remains constant. Preload is a tension created in screw when a torque force is applied to the screw head and is affected by the screw material’s properties. Preload produces a clamping force between the screw head and its seat. The behavior and durability of a screw joint depends mainly on the magnitude and stability of that clamping force. In this study, titanium screws were used, which have a higher friction coefficient than other materials, like gold.

Although the torque values have decreased after mechanical cycling, no movements of the replicas were observed macroscopically, which may indicate the maintenance of screw stability. Then, this torque loss may not immediately reflect in an evident loosening of the joint, but if the process is allowed to continue, it may result in joint instability and separation of abutment from the implant15,31, fracture, patient discomfort and biological complications, such as perimplantitis, because of the microgap created at the interface2. Further studies are required to verify the effects of a larger number of cycles on the long-term retention and stability of different abutments with external connection.

It is difficult to predict clinical results by in vitro studies because there are many factors affecting the oral environment, but the results of the present study allow suggesting that the use of cast or pre-machined UCLA abutments can present similar values of preload and torque loss after simulated use. It is also important to evaluate the mechanisms of the

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Table 1. Detorque data, expressed as percentage of initial torque.

Table 2. Comparison between cast and pre-machined UCLA abutments
abutment/implant retention screw joint with the study of stress distribution. Additional studies would be helpful to establish the clinical relevance of the present findings.

Within the limitations of this in vitro study, it may be concluded that the mechanical cycling, corresponding to one year of use, reduced the torque of the samples regardless if cast or pre-machined UCLA abutments were used.

References