Abutment Rotational Freedom Evaluation of External Hexagon Single-Implant Restorations after Mechanical Cycling

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ABSTRACT

Purpose: The purpose of this study was to evaluate the rotational freedom between implant and abutment counterpart of two abutments types over external hexagon implants submitted to mechanical cycling.

Materials and Methods: Ten implants with external hexagon (3.75 mm × 13 mm), five cast abutments, and five premachined abutments both with 4.1 mm plataform size were used in this study. Ten metallic crowns were fabricated using the two types of abutments and were fixed to each implant using titanium screws (Ti6Al4V). Rotational freedom measurements were made before and after the cast procedure and after the mechanical cycling. Groups were classified according to the rotational misfit register using University of California, Los Angeles abutment and implants as new (group 1 = G1); using crowns and implants after crown casting (group 2 = G2); and using crowns and implants after mechanical cycling (group 3 = G3). Oblique loading of 120N at 1.8 Hz and 5×10^5 cycles was applied on specimen.

Results: Statistical analysis ($p < .05$) showed that no significant difference was observed when cast abutment was compared with premachined abutment after casting ($p = .390$) and mechanical cycling ($p = .439$); however, significant difference was noted before the casting ($p = .005$) with higher values for the cast abutments.

Conclusions: Within the limitations of this in vitro study, it could be concluded that the abutment type used do not influenced the rotational freedom after casting and the amount of applied cycles (500,000 cycles) was not sufficient to significantly alter the values of rotational freedom at the implant/abutment joint.

KEY WORDS: external hexagon implant, mechanical cycling, rotational freedom, single-implant restorations

INTRODUCTION

The mechanical stability of the implant-supported fixed restorations may be considered to improve long-term stability and to minimize complications.[1] The stability of the connection between different implant parts is important for the success of the reconstruction, especially for single-tooth restorations. Loosening of abutment screws, mainly with the external hex implants, has been a technical problem that occurs during the first 2 years of the use.[2] 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.[3–5]

Studies that compared the complications of screw retained showed that the most frequent complication was related to abutment screw loosening (10–55.5%). The incidence of abutment screw loosening was 4.3% for the short-term studies and 10% for the long-term studies.[1]

Mechanical factors, such as the implant-abutment fit and the abutment screw preload are involved in the success of implant rehabilitation.[6] The preload loss during the occlusal load favors the misfit of the implant-abutment connection and could cause screw loosening

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and fracture and also affects the implant biological factors because the presence of a microgap, which may lead to peri-implantitis.[7] In vitro and clinical studies demonstrated the correlation between the rotation of the abutment and the prosthetic screw loosening and have showed the importance to reduce to a minimum the implant-abutment misfit to avoid mechanical complications.[3,8–10]

The hexagonal configuration prevents the abutment rotation on the implant surface and provides a stable screw joint assembly.[11] The amount of freedom between the implant hexagonal extension and its abutment counterpart has also been implicated as a factor in screw joint instability.[12] The torque applied, and the masticatory load could generate micromovements and deform the implant hexagon, studies indicate a direct correlation between implant-abutment rotational misfit and screw loosening.[9,13–16] Although external hex implants still dominate the European and US markets, the literature is lacking studies that compare the incidence of abutment screw loosening.[2]

The duration of the restorations can be affected by technical complications because different dental implants components are employed in both clinical and laboratory phases. Machined titanium, cast, and premachined abutments are still the most widespread solutions.[13] Cast abutments were introduced in order to provide more versatility on esthetic problems, solving many dilemmas.[17] The prosthetic components are important because the lack of prosthesis accuracy promote the screw loosening or fracture.

Then, the purpose of this study was to evaluate the rotational freedom between implant and abutment counterpart of 10 University of California, Los Angeles (UCLA)-type abutments (five cast and five premachined) cast in Ni-Cr and Ni-Cr-Ti alloys, respectively, over 10 external hexagon implants submitted to mechanical cycling.

MATERIALS AND METHODS

Ten implants with external hexagon (Titamax Ti Cortical, Neodent, Curitiba, Brazil) measuring 3.75 mm in diameter and 13 mm long, five cast UCLA abutments (Neodent) and five premachined UCLA abutments (Neodent) both with 4.1 mm plataform size were used in this study.

An experimental device was designed to measure rotational freedom angles between the abutment and implant. This apparatus consists of a device that locks the implant using two side screws, a graduated scale with 0.025° of accuracy, a rod to measure the rotational freedom angle, and a device fitted to the abutment with screws, as shown in Figure 1. A standard threaded 3.75×13 mm implant was secured in the table base of the apparatus with a set screw; the abutment was then attached to the implant with the abutment screw only to maintain abutment/implant stability. This initial point was marked when one of the vertices of the implant external hexagon touched one of the sides of the abutment internal hexagon. To obtain the initial point (t0), the rod was turned by hand in a counterclockwise direction until it encountered slight resistance from the connection. Then, the rod was moved in a clockwise direction until there was a slight resistance from the connection again or until the matrix hexagonal receptacle would bind with the patrix hexagonal (t1). Values of the angles read (t0 and t1) were recorded, and the difference between two values was recorded as the

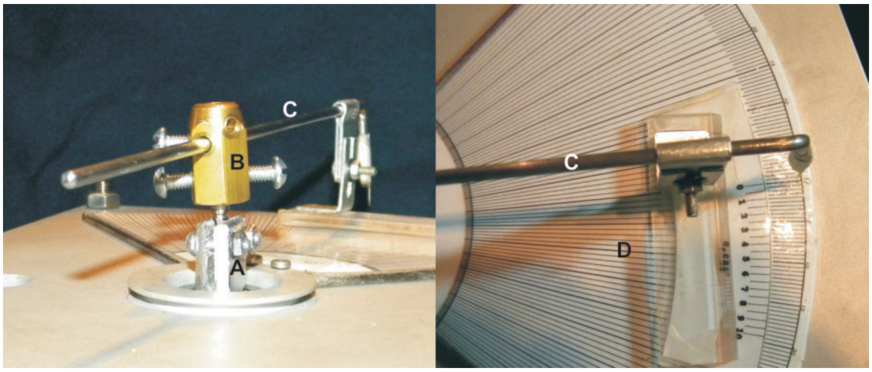

Figure 1 Experimental device designed to measure rotational freedom angles between the abutment and implant. *A* and *B*, Devices for locking the implant (A) and abutment (B). *C*, Rod to measure rotational freedom. *D*, Graduated scale with 0.025°.

amount of rotational freedom. Three measurements were made for each implant-abutment combination. The mean value for each sample was used to determine the group average.

The rotational freedom measurements were done in three situations: using UCLA abutment and implants as new (group 1 = G1); using crowns and implants after crown casting (group 2 = G2); and using crowns and implants after mechanical cycling (group = G3) (Figure 2).

Ten metallic crowns were fabricated using the two types of abutments: cast and premachined UCLA abutments. All crowns were fabricated according to a silicone matrix (Silicone Master, Talladium, Curitiba, 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 used a nickel-chromium alloy (Ni-Cr, Verabond II, Aalba Dent Inc., Cordelia, CA, USA) to the cast UCLA abutments and nickel-chromium-titanium alloy (Ni-Cr-Ti, Tilite Ômega, Talladium, Valencia, CA, USA) to the premachined UCLA abutments. Castings were allowed to bench cool, divested and airborne with 100 μm aluminum oxide (Polidental, São Paulo, Brazil) at 90 psi pressure, followed by water washing and air drying. No further polishing or finishing was performed. The crowns were fixed to each implant using titanium screws (Ti6Al4V) (Neodent).

The rotational freedom between crowns and implants was evaluated again by the same manner after crown casting (G2). The implants were embedded in acrylic resin (Jet, Classico, São Paulo, Brazil) in cylindrical polyvinyl chloride tubes 26 mm in diameter and 20 mm high, taking care to position the implants in the center of the tubes, using a metallic matrix to standardize the positioning with 30° of inclination in relation to the vertical axis.[9] The crowns were attached to the implants with titanium screws, applying a torque of 32N cm, according to manufacturer's recommendation. After 3 minutes, the screw was retightened to the same torque to minimize embedment relaxation. Each assembly was mounted in a holder of a custom-made level-type fatigue testing machine (machine for simulating fatigue tests with thermocycling – Elquip, Sao Carlos, Brazil). Dynamic oblique loading of 120N at 1.8 Hz was applied, totalizing 5×10^5 cycles with the assemblies immersed in distilled water at 37 ± 2°C during the mechanical cycling.[18]

After mechanical cycling, rotational freedom was evaluated again (G3), and the results were submitted to statistical analysis (SPSS 17.0, SPSS Inc., Chicago, IL, USA) by Kolmogorov–Smirnov normality test and mixed linear model, which is a generalization of the standard linear model (analysis of variance) used for the analysis of data in which the responses of the same specimen are grouped, and the assumption of

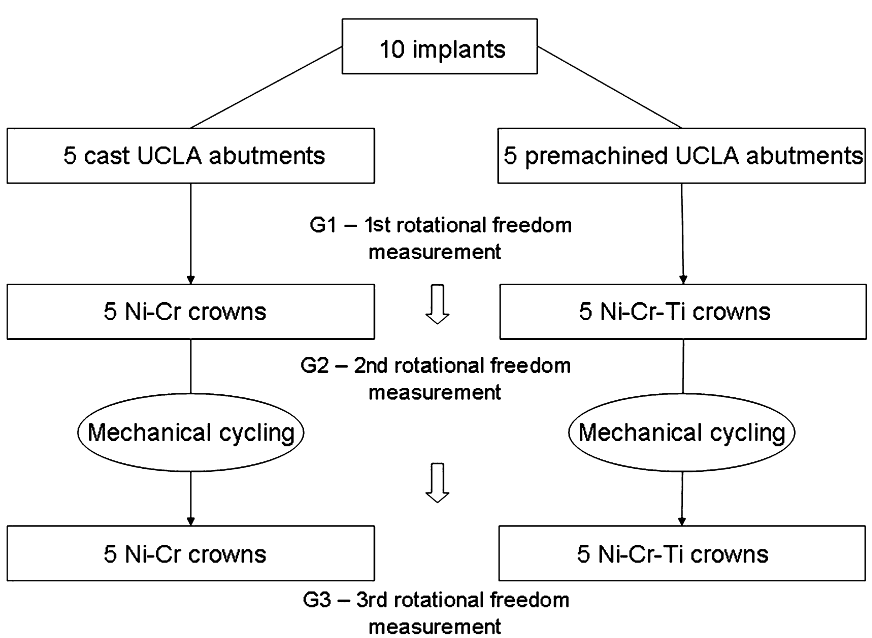

Figure 2 Schematic representation of the experimental groups. Ni-Cr = nickel-chromium alloy; Ni-Cr-Ti = nickel-chromium-titanium alloy; UCLA = University of California, Los Angeles.

TABLE 1 Means of Rotational Freedom Angles (°) and Standard Deviation (SD) for the Tests Groups

Groups	Abutment	Mean	SDs
G1	Castable	4.684	0.788
	Premachined	2.964	0.378
G2	Castable	3.210	1.369
	Premachined	4.512	2.826
G3	Castable	3.818	1.904
	Premachined	5.126	2.885

independence among the observations in the same group is not adequate.[19] Differences were considered significant when $p < .05$.

RESULTS

The results are summarized in Table 1. No significant difference was observed when cast abutment was compared with premachined abutment after casting ($p = .390$) and mechanical cycling ($p = .439$), but significant difference was noted before the casting ($p = .005$) (Table 2) with higher values for the cast abutments. However, any difference was noted among abutment before casting, crown before and after mechanical cycling for the cast or premachined abutments ($p > .05$), as shown in Table 3.

DISCUSSION

The rotational freedom is especially important to single-tooth applications because the exact seating is critical to interproximal contacts and optimal antirotational characteristics[12,20] in order to get antirotational stability.[10,11] The resulting misfit creates the potential for additional movement within the implant/abutment coupling once the effective screw preload has been dissipated by vibrations and micromovements within the screw joint as a consequence of functional loading.[21]

The dynamic of the implant complex assembly generated by a certain magnitude of torque loading is essential for understanding the response of any implant system to external loading.[22] When the abutment is joined to the implant by the abutment screw, three contact forces are generated: one at the abutment-to-abutment screw interface, another at the abutment-implant interface, and at the abutment screw thread-to-implant inner threaded interface. This last is defined as preload, and it is directly related to the torque applied. Applied torque and preload are indirectly proportional because of the influence of the friction forces under the head of the screw; the coefficient of friction is dependent of the hardness of the threads, the surface finishes, the quantity and properties of lubricant, and the speed of tightening.[21]

Preload is tension in a screw created when a torquing force is applied to the screw head. 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, otherwise retaining screws may yield or break under repeated functional bite forces. On the other hand, the preload values should not be too low, otherwise the retaining screws loosen under repeated functional forces.[23]

The stability of the implant/abutment connection and probability for screw loosening is also influenced by the preload because the screw tightening creates tension important to keep components together, offering a more stable joint.[12] Another variable that could influence the joint stability is how the contacting parts change when the screw is tightened because the microroughness of all the metallic surfaces slightly flattens and the microscopic distance between contacting surfaces decreases, which is called as "settling", and the preload is reduced.[24] In single-tooth implants, the preload is critical for screw joint integrity and for antirotational resistance.[3]

Many factors may cause reduction or loss of preload in single-tooth restorations such as cast procedures, superstrucuture inaccuracy, occlusal morphology and insertion torque, occlusal overload, and physical properties of screw material.[25,26]

Besides, it was concluded that hexagonal rotation of <5° is desirable for optimal joint stability and that reduction or elimination of patrix/matrix discrepancy and its potential for rotational movement will result in a more stable and predictable screw joint. The amount of rotation caused by eccentric loading might be dependent on the abutment rotational freedom within the hexagon play and the frictional forces that are created at the mating surfaces by tightening it.[27] An interesting result

TABLE 2 Rotational Freedom Comparison between Cast and Premachined Abutments (p > .05)

Groups	Comparison	Mean Difference	p Value	CI IL	CI SL
G1	Cast × Premachined	1.720	0.005	0.697	2.743
G2	Cast × Premachined	−1.302	0.390	−4.666	2.061
G3	Cast × Premachined	−1.308	0.439	−5.074	2.459

found in the present study was for the abutments comparison as new and after mechanical cycling procedures showing that the cast abutments presented greater values of rotational freedom than the premachined abutments. This may be due to the elastic memory of the cast components, once the contact between metal and plastic, at the moment of the rotational freedom degrees reading offered lower stiffness. Whereas the connection metal/metal provides greater friction, greater stability of the joint is ensured. In this study, the aim of using cast and premachined abutments as new was to observe the accuracy of the casting procedures and its influence of the abutment fit. The results observed were interesting for the tests.

Rotational stability can be achieved with abutments cast out of a cast abutment and that a restoration with rotational stability equivalent to that of machined components can be attained.[28] This is contrary to some published studies that have indicated that there is less screw loosening with premachined abutments than with cast abutments.[29] When casting alloys to a gold-machined UCLA abutment, the latter is exposed to the range and levels of temperatures required in the burnout and casting procedure. These manipulation processes, in addition to porcelain baking, may alter the abutment surfaces in contact with the implant and may lead to changes in the original horizontal fit at the implant cast abutment interface.[14,30] Specifically, casting procedures may cause imperfections and micro-irregularities in the contact surface that can affect rotational misfit and preload decreased, resulting in greater stress to the connection and failure of the restoration. In this study, the casting procedure altered the contact surface of some abutments but not enough to cause significant changes at the rotational freedom measurements. Another study[30] verified the fit of cast and premachined implant abutments that the 3i-machined abutments had fewer areas of contact with screws when subjected to casting and porcelain firing. It was concluded that this finding could be related to heat-inducing stress released within the premachined abutments during the laboratory procedures or distortion introduced by contraction of the surrounding casting. This problem also occurred in the present study and the reasons for this were probably the same. Also, the values found for the abutments were altered by the casting procedures, but this change was

TABLE 3 Rotational Freedom Comparison between Cast or Premachined Abutments as New, before, and after Mechanical Cycling (p > .005)

Groups	Comparison	Mean Difference	p Value	CI IL	CI SL
Cast	G1 × G2	1.474	.466	−1.422	4.370
	G1 × G3	0.866	1.000	−2.399	4.131
	G2 × G3	−0.608	.214	−1.504	0.287
Premachined	G1 × G2	−1.548	.535	−4.786	1.689
	G1 × G3	−2.162	.319	−5.813	1.489
	G2 × G3	−0.614	.291	−1.615	0.388

G = Group.

not sufficient to rise the degrees of rotational freedom. Comparisons between studies evaluating the effects of casting procedures are difficult because different criteria have been used for misfit of the castings.[28]

Screw joint failure by definition was designated as abutment mobility resulting from screw loosening, screw fracture, or implant fracture.[8] A retrospective study[31] verified that screw loosening often preceded more serious prosthetic complications such as implant fractures. In the present study, during mechanical cycling, it was observed that one of the assemblies of Ni-Cr-Ti crown/implant had greater movement than the other specimens as the load was applied. When the fatigue test is finished, it was observed that this assembly had its implant fractured.

The inherent machining tolerance of all the implant components must be reduced to a minimum to ensure intimate fit between the coupling surfaces of the abutment and the implant, and the same must be done to the accuracy of the laboratory casting procedures, allowing avoided mechanical and biological complications. The appropriate choice of the implant/abutment combination with low-machining tolerance, the selection of a suitable casting alloy, and the use of meticulous clinical and laboratory procedures are important in reducing rotational misfit and enhancing screw-joint stability.

CONCLUSIONS

Within the limitations of this in vitro study, it could be concluded that the abutment type used do not influenced the rotational freedom after casting and mechanical cyclic loading. When the two types of abutments, before casting procedure, were compared, better results of rotational freedom to the premachined abutments were found. The amount of applied cycles (500,000 cycles) was not sufficient to significantly alter the values of rotational freedom at the implant/abutment joint.

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