The Effect of Casting Procedures on Rotational Misfit in Castable Abutments

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Purpose: *Misfit of implant components has been linked to restorative complications such as screw loosening. Although previous studies have shown a correlation between rotational misfit and screw loosening, the impact of casting procedures on rotational misfit is lacking. The aim of this in vitro study was to evaluate the effect of casting procedures on rotational misfit of cast abutments when compared to machined titanium abutments.* ***Materials and Methods:*** *Forty-eight external hexagonal implants and 48 abutments were placed in 4 groups of 12 samples each:* (1) *machined titanium abutments,* (2) *premachined palladium abutments cast-on with palladium,* (3) *plastic burnout abutments cast with nickel chromium, and* (4) *plastic burnout abutments cast with cobalt chromium. Rotational misfit between the external hexagon of the implant and the internal hexagon of the abutment was measured using standardized techniques and recorded in degrees. Mean values for each group were analyzed with analysis of variance and Tukey test.* ***Results:*** *The mean rotational misfit was 1.21 ± 0.57 degrees for machined titanium abutments, 1.77 ± 130 degrees for cast-on abutments, 1.98 ± 0.72 degrees for cast NiCr abutments, and 2.79 ± 1.13 degrees for cast CoCr abutments. Significantly greater rotational misfit was recorded with cast CoCr abutments when compared to machined titanium abutments* ($P < .05$)*.* ***Conclusion:*** *Rotational misfit was less than 2 degrees for all groups except for cast CoCr abutments, which demonstrated a significantly greater rotational misfit.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:575–579

Key words: *abutments, implants, misfit, rotational misfit*

The implant-abutment connection is a joint consisting of 2 parts held together with a screw. The function of the screw is to create a clamping force between the implant and abutment sufficient to withstand external loads. When the implant-abutment interface is not accurately aligned because of misfit, part of the input torque is dissipated to align the component parts. When most of the input torque is used to align the parts, the remainder of the applied torque generates a less-than-optimal clamping force and results in a greater opportunity for screw-joint failure.[1]

Although a recent literature review reported that the incidence of screw loosening appears to be decreasing, screw-joint failures continue to be the most common complication in implant prosthodontics.[2] In 1 of the early reports of single implant-supported restorations, Jemt and Book[3] reported that 57% of abutment screws came loose during the first year and that only 37% remained stable throughout the entire 3-year follow-up period. A more recent 10-year retrospective study reported that abutment-screw loosening occurred in 7% of molar and premolar restorations.[4] In a retrospective study, Eckert et al[5] noted that screw loosening often preceded more serious prosthetic complications, such as implant fractures. Although improvements in component tolerances and interface and screw designs have decreased the incidence of screw loosening, the consequences of screw loosening remain substantial for both clinicians and patients.

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Scientific evidence is lacking to demonstrate the need of a passive-fitting prosthesis for long-term osseointegration.[3] However, lack of prosthesis passivity has been related to both screw loosening and screw fracturing.[1,6–8] It has been suggested that misfit should be kept to a minimum to avoid mechanical complications.[1,9,10]

Inherent in laboratory casting procedures are distortions and irregularities that may affect the fit and function of the implant restoration. Investigators have studied the impact of these laboratory casting errors on screw joint integrity.[11–14] Kano et al[11] reported that casting procedures decrease the percentage of applied torque and that machined abutments retained significantly greater detorque values compared to cast abutments. Byrne et al[12] reported that casting plastic burnout components resulted in more significant vertical marginal discrepancy as compared to cast-on premachined or machined titanium abutments. Carr et al[13] also compared cast plastic components, cast-on premachined components, and machined components using strain gauges at the abutment-component interface and determined that less preload was developed for all cast and cast-on components. This suggests that casting procedures may affect screw-joint integrity. However, when evaluating hex dimensions and rotation, Vigolo et al reported that casting procedures had no impact on premachined metal abutments.[14] Comparisons between studies evaluating the effects of casting procedures are difficult because different criteria have been used for misfit of the castings.

Investigators have shown that rotational misfit is an important measure of screw joint stability.[15,16] According to Jörnéus et al,[15] screw-joint stability improves when rotational misfit is decreased. Binon[16] evaluated the impact of increasing amounts of abutment rotation misfit on screw loosening from cyclic loading. This study demonstrated that when rotational misfit was increased from 2 to 3 degrees, the number of cycles required to cause screw loosening decreased by 26%.[16] Vigolo et al evaluated rotational misfit at the implant-abutment interface in cast-on premachined abutments. The results of the study indicated that there was no difference before and after casting procedures when the rotational misfit was kept under 2 degrees.[14]

Although previous studies have shown a direct correlation between rotational misfit[16–18] and screw loosening, the impact of casting procedures on rotational misfit of case plastic burnout abutments is unknown. The purpose of this in vitro study was to evaluate the rotational misfit of cast plastic burnout abutments and cast-on premachined abutments when compared to machined titanium abutments. The null hypothesis was that casting procedures would not negatively influence the rotational misfit at the implant-abutment interface.

MATERIALS AND METHODS

Forty-eight external-hexagonal implants (Conexão Sistema de Prótese, São Paulo, Brazil) were paired with 48 internal hexagonal abutments (Conexão Sistema de Prótese) and placed in 4 groups of 12 samples each: *(1)* machined titanium abutments, *(2)* premachined palladium abutment cast-on with palladium, *(3)* plastic burnout abutments cast with nickel chromium (NiCr), and *(4)* plastic burnout abutments cast with cobalt chromium (CoCr; Fig 1).

For group 1, titanium abutments were directly obtained from manufacturer in a conical shape 8 mm high and 8 mm across their widest diameter (Fig 1). Because the machined titanium abutments were not subjected to any type of casting procedure, they were used as a control group.

For groups 2, 3, and 4, premachined palladium cast-on abutments and plastic burnout abutments were waxed to the same basic shape as the machined titanium abutments from group 1. Each waxed abutment was attached to an implant, inserted into a lathe spindle, and refined to the same shape as the control abutment with a wax cutting blade. After waxing and shaping, the internal hexagonal abutment recess was carefully cleaned with monomer and alcohol. The wax patterns were individually invested with phosphate-bonded investiment (Termocast, São Paulo, SP, Brazil) and cast with the selected alloy (Table 1), using the conventional lost-wax casting technique according to the instructions of the alloy manufacturer. After casting, samples were allowed to bench cool. Divesting was carefully performed using glass beads (80 µm) at 1 bar pressure, followed by ultrasonic cleaning. No further polishing or finishing was performed. Prior to measurement of rotational misfit, samples from each group were selected randomly, and the hexagonal recess was viewed under a scanning electron microscope (SEM) and photographed.

Rotational misfit between the external hexagon of the implant and the internal hexagon of the abutment was measured using a calibrated protractor table previously described by Binon[16] and recorded in degrees (Fig 2). The implant was positioned into a split metal collet specifically designed to secure a 3.75-mm implant to the protractor table. The abutment was positioned and secured with an abutment screw tightened with light finger pressure (no torque was applied) to prevent the abutment from lifting during measurement phase. When the implant-abut-

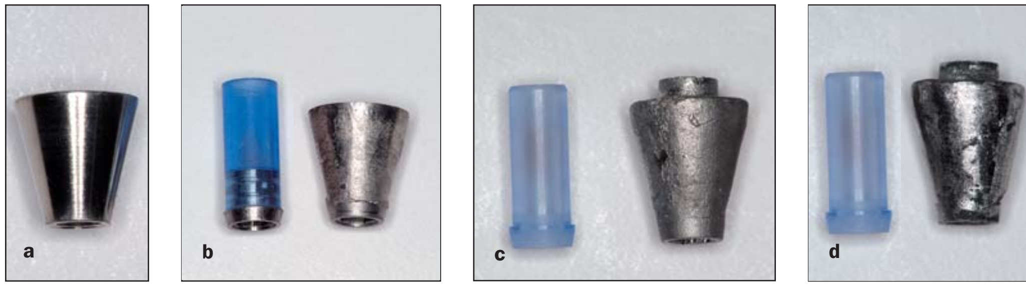

Fig 1 Paired internal hexagon abutments: *(a)* machined titanium abutment, *(b)* premachined palladium abutment cast-on with palladium, *(c)* plastic burnout abutment cast with nickel chromium, and *(d)* plastic burnout abutment cast with cobalt chromium.

Table 1 Casting Alloy Composition (%) and Melting Interval (°C)

Group	Alloy	Pd	Ag	Co	Cr	Ni	Melting interval
2	Pors-on 4*	57.8	30				1175 to 1275
3	VeraBond2†				12.5	77.05	1200 to 1315
4	CoCr Mold Alloy*			63	28		1320 to 1380

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†AalbaDent, Cordelia, CA.

Table 2 Results for Rotational Misfit (degrees)

Group	Mean	Maximum	Minimum	SD
1. Machined titanium abutments	1.21	2.0	0	0.57
2. Premachined palladium abutments cast-on with palladium	1.77	3.75	0	1.30
3. Plastic burnout abutments cast with nickel chromium	1.98	3.25	0.75	0.72
4. Plastic burnout abutments cast with cobalt chromium	2.79	4.25	0.50	1.13

ment assembly was positioned, a dial micrometer was used to apply pressure laterally to rotate the abutment and protractor arm. Two full rotations of the micrometer were applied to each sample to ensure that the same amount of load (160 g) was used to rotate the abutment of every implant-abutment combination measured. Placement of the sample in the measurement apparatus and the rotation of the abutment was conducted by the same investigator. The measurements were recorded by an investigator who was blinded to the sample being tested.

Three measurements were made for each implant-abutment combination. The mean value for each sample was used to determine the group mean. The mean values for each group were analyzed with ANOVA and the Tukey test, using group 1 as a control group.

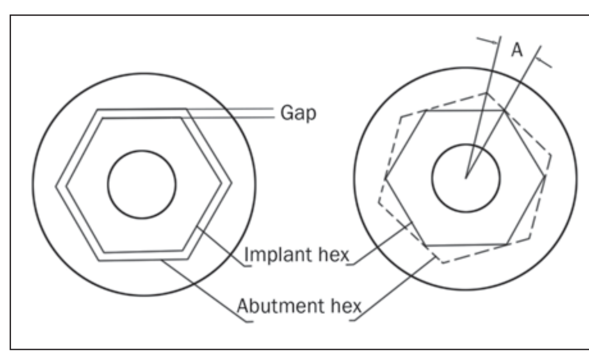

Fig 2 The difference between the external hexagon of the implant and the internal hexagon of the abutment results in a rotational misfit that can be measured in degrees (A).

RESULTS

Table 2 shows the results for each group, along with the standard deviation, maximum, and minimum values. Significantly greater rotational misfit was seen with CoCr abutments when compared to machined titanium abutments ($P < .05$). Imperfections did not affect the rotational misfit of the premachined cast-on abutments and plastic burnout abutments cast with NiCr when compared to machined titanium abutments.

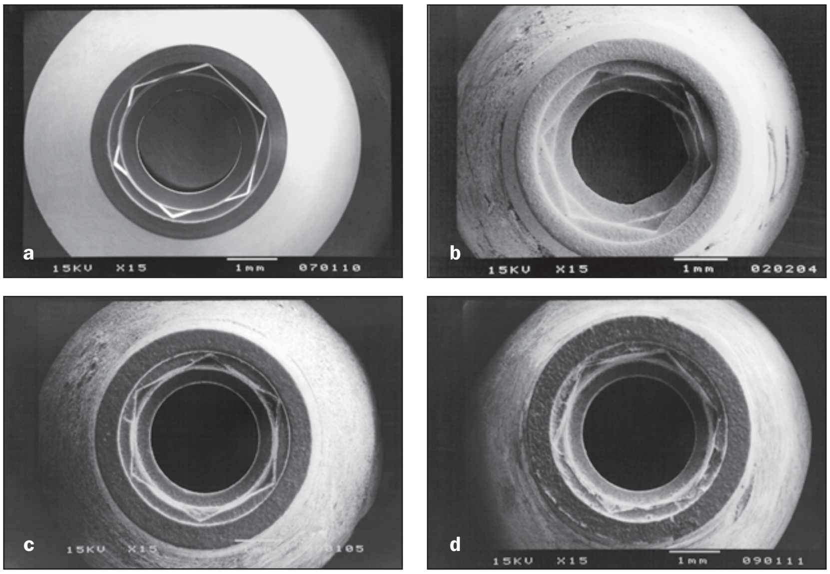

Fig 3 SEM photographs of the internal hexagon of *(a)* a machined titanium abutment, *(b)* the premachined palladium abutment cast-on with palladium, *(c)* a plastic burnout abutment cast with NiCr, and *(d)* plastic burnout abutment cast with CoCr.

DISCUSSION

When an abutment screw loosens, the clinician is often unsure why it happened and what laboratory steps may have contributed to the screw loosening. Reports in the literature have indicated that there is less screw loosening with premachined abutments than with cast abutments.[2,16] However, results obtained in this study showed that rotational stability can be achieved with abutments cast out of a plastic burnout component and that a restoration with rotational stability equivalent to that of machined components can be attained.

In this study, the NiCr abutments presented less than 2 degrees of rotational misfit, which is comparable to machined titanium abutments and premachined palladium abutments cast-on with palladium. According to Binon,[16] rotational misfit at the implant-abutment interface of less than 2 degrees resulted in the most stable screw joint and required an average of 6.7 million cycles for screw loosening.

In contrast, the CoCr cast abutment group had significantly higher rotational misfit than machined abutments, with a mean value of 2.79 degrees. According to Binon,[16] when rotational misfit increased from 2 degrees to 3 degrees, the average number of cycles until screw loosening decreased from 6.7 million cycles to 4.9 million cycles (26%). The significantly higher rotational misfit of the CoCr cast abutments reported in this study may therefore have clinical significance.

Carr et al[13] reported that finishing and polishing procedures improved the preload values for plastic burnout abutment patterns cast with noble alloys. They reported that casting imperfections were minimized with this procedure. In the present study, none of the cast components were submitted to any finishing or polishing procedures. Since base metal alloys are more difficult to finish and polish than noble alloys, further comparison between noble alloys and the base metal alloys used in this study is necessary to confirm the effect of finishing and polishing procedures. SEM micrographs of the internal hexagon of representative abutments of this study demonstrated that casting procedures produced imperfections and microirregularities in the contact interface (Fig 3). Visual observation indicated that the level of imperfections in the CoCr group was notably greater. Imperfections did not affect the rotational misfit of the premachined cast-on abutments and plastic burnout abutments cast with NiCr when compared to machined titanium abutments. Previous studies have reported that premachined metal abutments were not altered by casting procedures when evaluated for marginal fit,[12] preload,[13] and rotational misfit,[14] and component integrity was therefore maintained throughout the laboratory procedures. Binon[16] has demonstrated the relationship between rotational misfit and screw joint stability using machined titanium abutments. However, further studies are needed to confirm this relationship when plastic burnout abutments are used. A comparison of plastic burnout abutments from different manufacturers submitted to the same casting procedure may further elucidate on this relationship.

CONCLUSIONS

Within the limitations of this study, the premachined palladium cast-on abutments and the plastic burnout abutments cast with NiCr had less than 2 degrees of rotational misfit and can attain optimal rotational screw joint stability. The plastic burnout abutments cast with CoCr exceeded 2 degrees of rotational misfit. Casting plastic burnout abutments with CoCr is contraindicated if optimal rotational screw joint stability is to be attained. All of the cast abutments demonstrated greater rotational misfit than the machined titanium abutments; however, the results obtained in this study showed that the rotational stability achieved with plastic burnout abutments cast with NiCr was equivalent to that achieved with machined components. Casting procedures can affect rotational misfit.

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