Effect of Casting Procedures on Screw Loosening in UCLA-Type Abutments

Stefania Kano, DDS, MS, PhD;[1] Donald A. Curtis, DMD;[2] Paul Binon, DDS, MSA;[3] and Gerson Bonfante, DDS, MSc, PhD[4]

Background: Screw loosening of implant restorations continues to be a complication in implant prosthodontics. Screw joints are subjected to a loss of initially applied torque because of friction and component misfit. It has been suggested that the loss of applied torque is less in machined metal abutments than in cast plastic abutments.

Purpose: This study compared the loss of applied torque (detorque) values in machined titanium and in cast UCLA-type abutments for external hex abutment/implant interface.

Materials and Methods: Four groups of 12 samples each were evaluated: (1) machined titanium abutments, (2) premachined palladium abutments cast with palladium, (3) plastic abutments cast with nickel-chromium, and (4) plastic abutments cast with cobalt-chromium. Each abutment was torqued to 30 Ncm according to the manufacturer's instructions and detorqued three times. The mean loss of applied torque (detorque) was recorded as a percentage of the torque applied. Group means were calculated and compared using ANOVA and Tukey's LSD test.

Results: Mean detorque values were (1) 92.3 ± 2.9%, (2) 81.6 ± 5.0%, (3) 86.4 ± 4.6%, and (4) 84.0 ± 7.0%. Machined abutments demonstrated significantly greater detorque values compared with all cast groups ($p < 0.05$). No significant differences were found among cast groups.

Conclusion: Machined abutments retained a significantly greater percentage of torque compared with cast abutments. Casting procedures decrease the percentage of applied torque, which may influence final screw joint stability.

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INDEX WORDS: implants, screw loosening, implant abutments

SCREW LOOSENING has been reported as the most common restorative complication, especially in single units in the premolar and molar areas.[1-3] Jemt et al observed screw loosening in 49% of maxillary implant prostheses and 20.8% of prostheses in the mandible over a 3-year period.[3] In single tooth restorations, Jemt et al observed that 57% of abutment screws loosened during the first year and only 37% remained stable throughout a 3-year follow-up.[2] Although improvements in material and protocol have decreased the incidence of screw loosening,[4] a recent 10-year retrospective study determined that abutment screw loosening occurred in 7% of molar and bicuspid restorations.[5]

The component interface geometry, amount of machining tolerance provided, and component passivity can impact the potential for screw loosening. A wide-diameter implant/abutment platform has been shown to improve stability and resistance to screw loosening in in vitro cyclic loading experiments.[6] Tight fit of components requires stringent machining tolerances; if excessive tolerances are used, flexural fatigue can also result in screw loosening.[7] The absence of passivity between components has also been shown to increase stress in the screw and results in metal fatigue failure and screw loosening.[6-8] Although evidence

[1]*Associate Professor, Department of Prosthodontics, Bauru School of Dentistry-USP, Brazil.*

[2]*Professor, Division of Prosthodontics, Department of Preventive and Restorative Dental Sciences, University of California, San Francisco School of Dentistry, San Francisco, CA.*

[3]*Assistant Professor, Department of Prosthodontics, Indiana University School of Dentistry, Indianapolis, IN.*

[4]*Assistant Professor, Department of Prosthodontics, University of São Paulo, São Paulo, Brazil.*

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Correspondence to: Stefania Kano, Department of Prosthodontics, Bauru School of Dentistry-USP, Al. Otavio Pinheiro Brizola 9-75, Bauru SP 17012-901, Brazil. E-mail: stekano@uol.com.br

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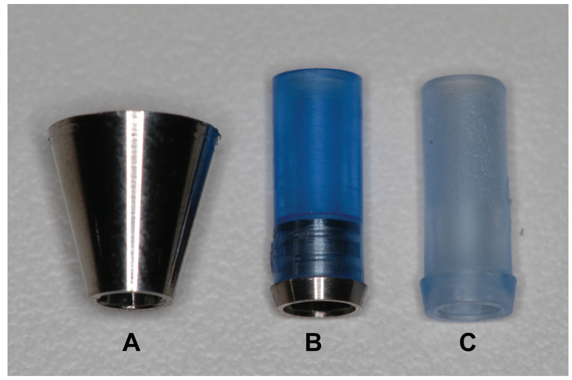
is lacking to demonstrate the need of a passive fitting prosthesis for long-term osseointegration, poor component fit and excessive component tolerances have been shown to contribute to screw loosening.[6–8]

The stability of the implant/abutment connection and propensity for screw loosening is also influenced by the preload. Tightening the screw creates the tension in the screw (called preload) necessary to keep the components together. The greater the joint preload, the greater the resistance to loosening, and the more stable the joint.[9] A second variable influencing the joint stability is how the contacting parts change when the screw is tightened. After being tightened together by the screw, the micro-roughness of all the metal-contacting surfaces slightly flattens and the microscopic distance between contacting surfaces decreases. As a result of this process called "settling," the screw loses part of its preload.[6] Consequently, the clamping force that keeps the components together is also reduced. For this reason, detorque values immediately after tightening are always lower than the initial tightening torque.[10–12] Any irregularities in the matting surfaces will likely result in preload reduction because the input torque is used to flatten the rough surface rather than elongating tension in the screw to generate a clamping preload.[10]

Preload can be influenced by component and screw materials,[10,13] torque delivery systems,[14] manufacturer quality control,[15] screw joint design,[16] surface roughness,[17] and fatigue testing.[11,18] Optimal preload values are reported to be 300 N for gold cylinder/abutment joints;[19] however, the optimal preload values for the implant/abutment screw joint have not been fully identified. In single tooth implants, implant/abutment screw joint preload is critical for screw joint integrity and for antirotational resistance. Preloads for single tooth abutments have been reported at 643.4 N for the Ceraone (NobelBiocare, Yorba Linda, CA) and 556.9 N for the TiAdapt abutments (Nobel Biocare).[15]

To date there have been few in vitro comparisons of abutment screw loosening in milled solid abutments, premachined abutments, and plastic abutments cast with various alloys. The purpose of this study was to evaluate the effect of casting procedures on the loss of applied torque (detorque) in machined titanium abutments, premachined cast abutments, and plastic cast abutments.



COLOUR FIG.

Figure 1. (*A*) Machined titanium abutment; (*B*) premachined palladium abutment with plastic sleeve; and (*C*) plastic abutment.

Materials and Methods

Forty-eight randomly selected external hexagonal implants, Branemark clones, with a 3.75 mm platform, (Conexão Sistema de Prótese, São Paulo, Brazil) and 48 abutments (Conexão Sistema de Prótese) were placed in four groups of 12 samples each and paired with: (1) machined abutments, (2) premachined palladium abutments with plastic sleeve cast with palladium, (3) plastic abutments cast with nickel-chromium alloy (Ni-Cr), and (4) plastic abutments cast with cobalt-chromium alloy (Co-Cr) (Fig 1).

For each combination of implant and abutment, one titanium alloy abutment screw was used.

For Group 1, titanium abutments were machined by the manufacturer in a conical shape 8 mm high and 8 mm across at their widest diameter (Fig 1). Because the machined titanium abutments were not subjected to any type of casting procedure, it was used as a control.

Casting Procedure

For Groups 2, 3, and 4, abutments were waxed to the same dimensions as the abutments from Group 1. All waxing and casting were completed by one individual for consistency. The wax patterns were individually invested using phosphate-bonded investment (Termocast, Polidental Indústria Comércio Ltda, São Paulo, Brazil) and cast with palladium, nickel-chromium, or cobalt-chromium alloy (Table 1). After casting, specimens were allowed to bench cool and divesting was carefully performed using glass beads with 2.8 bar pressure. No further polishing or finishing was performed.

Table 1. Casting Alloy Composition (%) and Melting Interval

Group	Alloy	Pd	Ag	Co	Cr	Melting Interval (°C)
2	Pors-On 4*	57.8	30			1175 to 1275
3	VeraBond2†				12.5	1200 to 1315
4	Co-Cr model casting alloy*			63	28	1320 to 1380

*Degudent, Guarulhos, Brazil.
†AalbaDent, Cordelia, CA.

Table 3. Mean Screw Loosening Torque (Detorque) for Premachined Palladium Abutments Before and After Casting

Premachined Palladium Abutments	Detorque (%)
Before casting	86.4 ± 4.87
After casting	81.6 ± 5.0

The amount of torque required to loosen the abutment was averaged for each group and recorded as a percentage of initially applied torque.

Detorque Analysis

Detorque values were determined for the premachined palladium abutments (Group 2) before casting. This was completed to provide baseline values prior to casting. Precasting values were not possible in Groups 3 and 4 where plastic abutments were used.

Each implant/abutment assembly was positioned in a holding vice and the titanium screw was tightened to 30 Ncm according to manufacturer's instructions using a calibrated torque gauge (Tohnichi Torque Gauge, Tohnichi America, BTG 60, Japan). After 3 minutes, the screw was loosened and the torque required to loosen the screw was recorded. This procedure was repeated three times for each sample. The torque required to loosen the screw (detorque) was recorded as a percentage of the applied torque. Group means were calculated and compared by one-way ANOVA and Tukey's LSD test with $\alpha = 0.05$. A paired t-test was used to evaluate detorque values for premachined palladium abutments before and after casting.

Results

Machined titanium abutments (Group 1) retained 92.3 ± 2.9% of the 30 Ncm torque initially applied while premachined palladium abutments cast with palladium (Group 2) retained 81.6 ± 5.0% of the 30 Ncm torque applied (Table 2).

Plastic abutments cast with Ni-Cr (Group 3) and Co-Cr (Group 4) retained 86.4 ± 4.6% and 84.0 ± 7.0%, respectively, of the 30 Ncm torque initially applied. Machined titanium abutments (Group 1) retained a significantly greater percentage of torque when compared to all cast groups ($p < 0.05$). No differences were found when comparing cast groups.

Detorque values for premachined palladium abutments were evaluated before (86.4 ± 4.87%) and after casting (81.6 ± 5.07%) and a paired t-test showed statistically significant differences (Table 3).

Table 2. Mean Screw Loosening Torque (Detorque) Obtained, as a Percentage of Initially Applied Torque

Groups	Detorque (%)
1. Machined titanium abutment	92.3 ± 2.9
2. Pre-machined palladium abutment cast-on with palladium	81.6 ± 5.0
3. Plastic abutment cast with Ni-Cr	86.4 ± 4.6
4. Plastic abutment cast with Co-Cr	84.0 ± 7.0

Discussion

Detorque values for all groups were less than the initial tightening torque and ranged from 81.4% to 92.3% of the initial tightening torque. These results are consistent with findings of Haack et al[10] and Schulte and Coffey;[16] however, detorque values for the machined titanium abutments were higher in our study than detorque values observed by three other investigators.[10,11,16] Haack et al determined detorque values that ranged from 70% to 80% of the initially applied torque when using gold UCLA hexed abutments with gold and titanium screws.[10] Schulte and Coffey investigated the screw-loosening torque of nine abutment systems and determined detorque values that ranged from 80% to 93% of tightening torque, with the titanium UCLA abutment retaining only 81% of the applied torque.[16] Dixon et al evaluated detorque values in external hexagonal titanium abutments to be 83.3% prior to loading.[11] The difference in results of detorque values is in accordance with previous studies demonstrating that components from different manufacturers may produce different detorque values.[6,9]

Previously, it has been shown that preload is significantly reduced when abutment components are cast, and that this influence can be minimized if the contacting surface is finished and polished.[17] The loss of detorque values in premachined abutments (Group 2) was consistent with the detorque values seen in plastic cast abutments. This finding supports the notion that casting procedures can decrease detorque values even in premachined cast abutments. This may be because casting often produces irregularities and roughness of contacting surfaces that may result in greater embedment relaxation and greater loss of preload.[6,17] SEM pictures of the contact surface showed that cast abutments from plastic abutments (Groups 3 and 4) or premachined metal abutments (Group 2) presented roughness and some irregularities, while machined abutments presented a smooth and well-finished contact surface (Fig 2).

Statistically significant differences were found for detorque values of the premachined palladium abutment before (86.4 ± 4.87%) and after (81.6 ± 5.07%) casting, whereas significant differences in preload were reported by Carr et al.[17] They showed that the effect of casting in premachined palladium abutments was manufacturer dependent, with some manufacturer abutments were significantly affected by the casting procedure. This difference may suggest that material properties of metal components can be altered during casting. Haack et al obtained detorque values of 70% to 80% of initially applied torque, resulting in preload values of 468.2 N for gold alloy screws and 381.5 N for titanium screws at the implant/abutment screw joint.[9] Detorque values in our study ranged from 81.4% to 92.3% of the initial tightening torque.

Further studies are required to more fully understand the different influences that can cause loss of torque values in implant abutments. Although our results indicate that casting procedures can influence the loss of applied torque in an unloaded in vitro environment, additional clinical studies would be helpful to establish the clinical relevance of our findings.

Conclusions

Within the limitations of the study, the following may be concluded for the specific implant system used:

1. Machined titanium abutments retained a significantly greater percentage of the 30 Ncm applied torque than cast abutments.

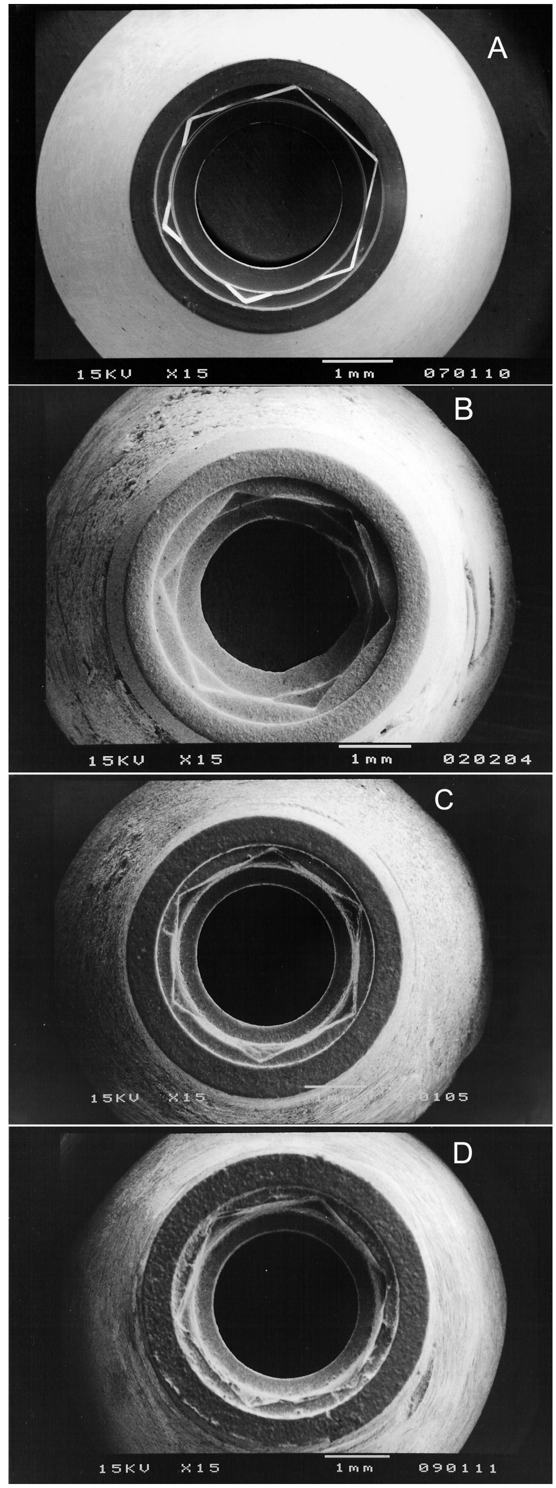


Figure 2. SEM pictures of all groups: (*A*) machined titanium abutments; (*B*) premachined palladium abutment cast with palladium; (*C*) plastic abutment cast with nickel chromium; and (*D*) plastic abutment cast with cobalt chromium.

2. No significant difference of detorque values was noticed among cast abutments.

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