Use of Acid for Oxide Layer Removal of Overcast UCLA Abutments: Influence on Fit and Roughness

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Purpose: The objective of this study was to evaluate the influence of the oxide layer removal procedure using acid on the roughness and internal fit of overcast universal castable long abutments (UCLAs) for a taper connection. ***Materials and Methods:*** For this, maxillary first premolars were waxed on the plastic sleeve of 15 UCLAs with a premachined interface. The specimens were overcast using the NiCr alloy, and the frameworks were randomly distributed to undergo one of two different oxide layer removal methods: blasting with 100-µm particles of aluminum oxide at 0.60-MPa pressure or bathing for 5 hours in 0.5% hydrofluoric acid. The surface roughness was evaluated by a light interferometer at the subcritical contour of each abutment. Next, the frameworks were attached to the respective analogs for internal fit evaluation. The central cross section of each assembly was exposed, and three regions were visualized by scanning electron microscopy (SEM): taper interface, axial wall, and index region. The premachined base was used as the control. The groups were compared using analysis of variance (ANOVA) and Tukey post hoc test ($\alpha = .05$). ***Results:*** The results showed that acid bathing produced intermediary roughness between premachined and blasted surfaces ($P < .05$). SEM images showed a sealed interface at the taper region of all groups, despite some irregularities after alumina blasting. Increased discrepancies at the axial wall and index region were found after the alumina blasting procedure ($P < .05$). ***Conclusion:*** It was concluded that acid bathing should be used, instead of blasting to remove the oxide layer, to produce a better fit and smoother surface on UCLAs. *Int J Oral Maxillofac Implants 2021;36:289–294. doi: 10.11607/jomi.8584*

Keywords: abutment, internal connection, prosthetic procedure, surface

Implant-supported single crowns are usually supported by a transmucosal abutment connected to the implant by torquing a connecting screw.[1] Thereafter, a tight fit of the implant-abutment interface is required for the reliability and stability of this bolted joint.[2,3] The optimum fit depends on stringent machining tolerances; otherwise, excessive tolerances can result in screw loosening by flexural fatigue.[4,5] Although the development of internal implant-abutment connections provided a biomechanical advantage over the external hexagon design,[6,7] internal connections also require an accurate fit to keep the abutment stable on the implant.[8–11]

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Customized universal castable long abutments (UCLAs) were designed to correct implant angulation or depth issues. Custom abutments can be cast to correct up to 30-degree divergence between adjacent implants or implant placement that is too deep. Moreover, UCLAs can be used to manufacture the crown directly on the implant platform when shallow implants need to be restored. These components were initially designed for casting with precious metals and are now also made of non-noble alloys such as CoCr alloy because of the reduced cost compared with noble alloys, biocompatibility, and ease of casting.[12] Because a castable interface cannot be as accurate as a machined interface,[13] UCLAs are presented with a plastic sleeve to be overcast on a metal base to improve fit of the abutment.[14]

However, overcasting produces an oxide film on the prefabricated metal interface that needs to be removed. Usually, it is removed by blasting the surface with alumina particles; however, this procedure can influence roughness at the subcritical contour, as well as marginal and internal fit of the abutment. There is no information in the literature about the influence of oxide layer removal by acid on abutment roughness and fit. Therefore, the objective of the present study was to evaluate the influence of oxide layer removal by acid

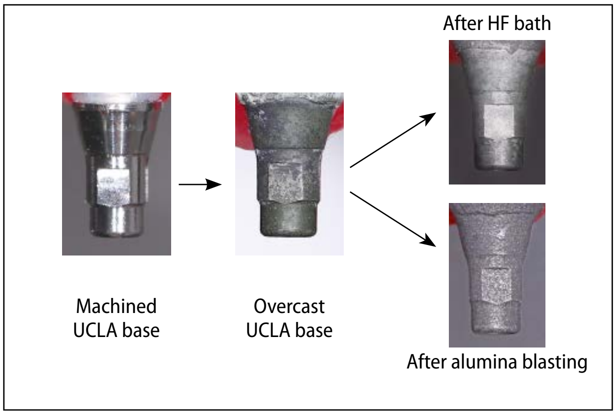

Fig 1 Surface morphology of the machined surface and the overcast surface with the oxide layer and after acid bathing or alumina blasting for oxide layer removal.

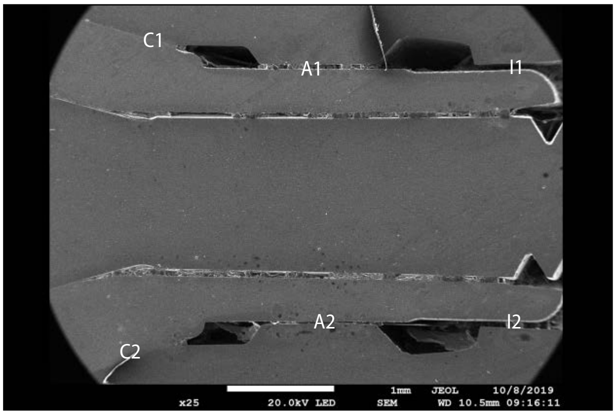

Fig 2 The implant-abutment interface fit was measured at the taper (C1 and C2), axial (A1 and A2), and index regions (I1 and I2) on both sides.

on the roughness and internal fit of overcast UCLAs for a taper connection. The null hypothesis was that acid treatment does not promote a smoother surface and better fit of overcast abutments.

MATERIALS AND METHODS

Twenty maxillary first premolars were waxed on the plastic sleeve of the UCLAs with a CoCr premachined base (EFF) compatible with a regular CrossFit implant connection (Straumann) using a low-shrinkage acrylic resin (Duralay II, Reliance Dental) and a silicone mold to standardize the crown design. Fifteen specimens were included in investment material (Bellavest SH, Wilcos) to be overcast with NiCr alloy (Mesa, Wilcos). After casting, 10 metal frameworks were randomly distributed to undergo one of two different oxide layer removal methods (Fig 1): blasting with 100-µm particles of aluminum oxide at 0.60-MPa pressure or bathing for 5 hours in 0.5% hydrofluoric acid (Empress acid, Ivoclar) at room temperature (n = 5). A vertical support was used to allow only the implant-abutment interface to be immersed in the acid solution. After complete oxide layer removal, the frameworks were cleaned with water and alcohol for 10 minutes each using an ultrasound bath.

The surface roughness was evaluated by a light interferometer (NewView 9000, Zygo). Three random areas at the subcritical contour of each abutment were evaluated, and the arithmetic average of the roughness profile (Ra) was recorded. Next, the frameworks were attached to the respective analogs with the recommended torque of 35 Ncm using a torque wrench. For fit evaluation, the sets were embedded into thermoplastic phenolic resin (Baquelite MP39, Fortel) using a metallographic press (EFD 40, Fortel) and were cut using a diamond disk (IsoMet Low Speed Saw, Buehler). The central cross section was reached using 400- and 600-grit silicon carbide abrasive papers.[15]

The cross section was visualized by scanning electron microscopy (SEM; JEOL) at 500× and 1,500× magnifications. The internal fit was evaluated at three predetermined regions at the taper, axial wall, and index regions, as shown in Fig 2.[16,17] All measurements were taken by one blind operator (N.D.P.), and the mean value between the right and left measurements was considered for each set. The groups (premachined, alumina-blasted, and acid-treated) were compared using analysis of variance (ANOVA) and Tukey post hoc test at a significance level of .05 (SPSS v.20, IBM).

RESULTS

Both methods were effective in removing the oxide layer produced by the casting procedure. The use of low-concentration acid solution created a more uniform flat surface with some sparse peaks, while alumina blasting clearly produced a rougher surface (Fig 3). The surface topography of the etched surface was more similar to the machined surface than the use of alumina blasting.

The Ra values, which represent the average height considering surface peaks and valleys, can be seen in Table 1. The oxide layer produced the roughest surface with the overcasting procedure ($P < .05$). Although alumina blasting was effective in removing the oxide layer, it was not able to produce a smoother surface compared with the acid treatment.

SEM images demonstrated a sealed interface at the taper region of all groups, despite increased roughness and some irregularities in the alumina-blasted group (Fig 4). However, the internal discrepancies of the axial and index walls were smaller in the premachined group (Table 2). The alumina blasting procedure produced a

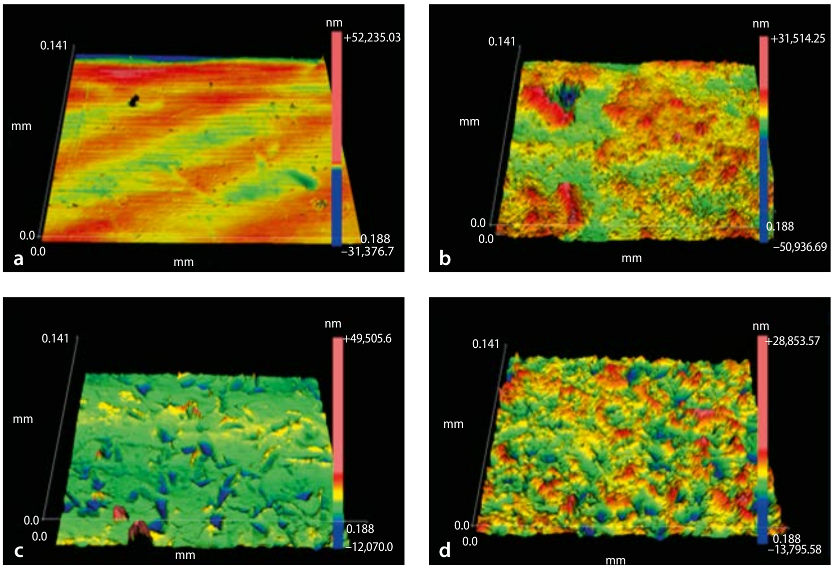

Fig 3 Surface roughness of the *(a)* machined base, overcast surface *(b)* before and *(c)* after acid bathing, or *(d)* alumina blasting for oxide layer removal.

Table 1 Surface Roughness at the Subcritical Contour of Machined and Overcast CoCr Bases Before and After Removal of the Oxide Layer with Acid Bathing or Grit Blasting (Mean and SD)

Group	Ra (µm)
Machined	0.5 ± 0.2[a]
Overcast	3.4 ± 0.5[b]
Acid	1.0 ± 0.3[c]
Blasting	1.7 ± 0.3[d]

Ra = average height profile. Different letters indicate significant difference between the groups.

Table 2 Internal Fit (µm) of Implant-Abutment Interface at the Taper, Axial, and Index Walls of Premachined and Overcast CoCr Bases After Removal of Oxide Layer with Acid Bath and Grit Blasting (Mean and SD)

Interface region	Premachined base	Overcast after acid bath	Overcast after blasting
Taper wall	0.000 (± 0.000)[a]	0.001 (± 0.001)[a]	0.003 (± 0.001)[a]
Axial wall	20.7 (± 2.6)[a]	35.0 (± 13.1)[b]	49.3 (± 22.1)[c]
Index wall	52.1 (± 9.1)[a]	64.7 (± 12.1)[b]	69.9 (± 20.1)[b]

Different letters indicate significant differences between the groups.

higher discrepancy at the axial wall than the acid bathing ($P < .05$).

DISCUSSION

A precision of fit between the implant and abutment is important for the long-term stability of a prosthesis. Overall, taper connections provide an improved microbial seal and better joint strength that prevent screw loosening.[14] The present study demonstrated that all UCLAs have a proper sealing at the taper region. However, the oxide removal procedure produces irregularities and roughness of contact surfaces that result in greater embedment relaxation and greater loss of preload.[8] Thus, a surface roughness closer to the machined surface is desired. A previous study reported that the preload maintenance could be improved if the cast surface is finished and polished[18]; however, any attempt of the technician to finish or polish the implant-abutment interface using rubber points with a handpiece, irrespective of previous laboratory procedures, would not create a sealed interface.

The advent of CAD/CAM systems introduced the use of different materials and new laboratorial procedures[19,20]; however, the conventional lost-wax casting technique is still a clinical reality. The manufacture of a personalized abutment or a framework by the overcasting process would be done in daily practice for financial reasons with no prejudice of marginal fit.[21] Thus, the present study proposes the use of a low concentration of hydrofluoric acid solution, commonly used to remove the investment material for the old Empress ceramic system (Ivoclar), to remove the oxide layer from the casting procedure. In contrast to the more concentrated HF solutions used to treat the surface of titanium to improve osseointegration,[22] the present study demonstrated that 0.5% HF can be effective in oxide

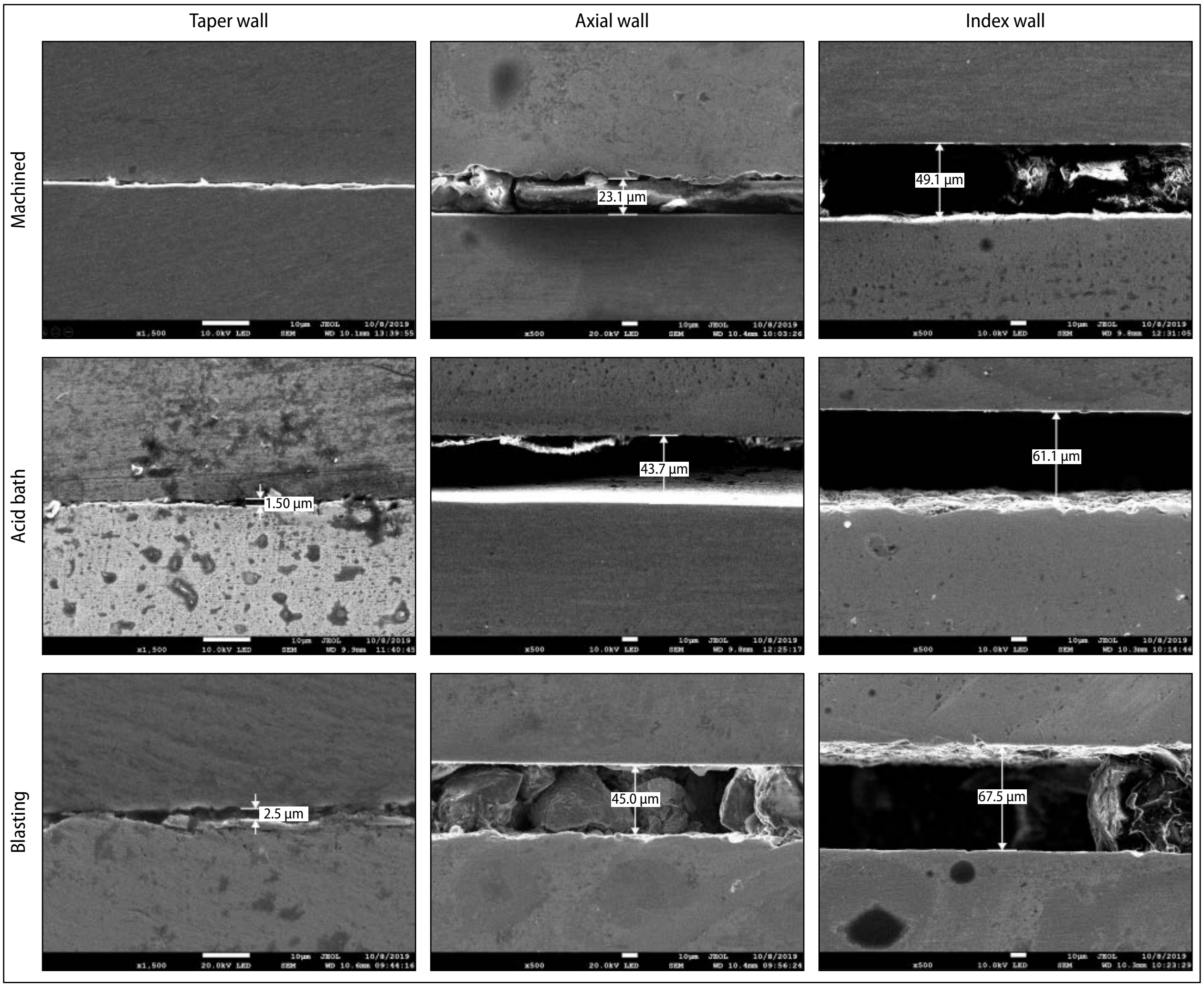

Fig 4 SEM images of the implant-abutment interface at the taper wall (×1,500) and axial and index walls (×500) of the CoCr bases before and after acid bath and blasting.

layer removal. However, it is not often used for metal-ceramic restorations because it interferes with the oxide layer for subsequent ceramic adhesion to the metal. Therefore, this acid must be applied only to the metal base and not the metal surface that will be coated with ceramic. It can be done with the aid of a vertical support to hold the abutment and control the immersion level of the abutment.

The results demonstrated that acid bathing produced a better fit and smoother surface than alumina blasting. Although the ideal misfit would be no marginal gap, interface gaps < 10 µm have been established as a clinical threshold for minimum biologic and/or mechanical complications.[23] In the present study, the average microgap at the taper region of the premachined abutment and the acid-treated group were 0 ± 0 µm and 2 ± 1 µm, respectively. Considering that a microbe can have < 2 mm in diameter,[24] a better seal against bacterial colonization in these groups can be presumed compared with the grit-blasted group, which exhibited a mean gap of 3 ± 1 µm. Further studies should investigate if the increased roughness produced by the alumina blasting at the taper interface would reduce its sealing capacity.

On the other hand, a clinical threshold for the internal misfit has not been defined yet. It is important because despite an intimate fit at the taper interface, a worse fit of the axial and index walls would cause higher rotational freedom and micromovements of the abutment that interfere with microleakage and screw preload maintenance, especially under loading.[25] Although a previous study demonstrated that better internal fit can be associated with original abutments (implant and abutment from the same manufacturer),[26] which would reflect in a lower incidence of mechanical failure,[27] original abutments and nonoriginal abutments (compatible abutments from a different manufacturer) were found to be clinically acceptable.[23] In the present study, a compatible component premachined UCLA was used, and the overcast procedure increased the internal misfit. However, the acid-treated surface presented a lower misfit at the axial wall compared with the alumina-blasted interface.

Considering the subcritical and critical contour surfaces of the abutment, a smoother surface would minimize the long-term risk of a higher degree of inflammation in the peri-implant tissues.[28,29] Thus, minimal roughness is desired to prevent attachment loss and biofilm accumulation.[30] In this way, the acid-treated surface would be more advantageous than the grit-blasted surface in preventing biofilm formation. Although previous studies reported a similar response of fibroblasts to machined and acid-treated titanium surfaces[31,32] and enhanced junction epithelium attachment to a hydrofluoric acid-modified titanium surface,[33] there is a lack of information about the behavior of soft tissue on grit-blasted surfaces. The present study on the use of acid for oxide layer removal produced an intermediary surface roughness between the machined and blasted surfaces and would present improved soft tissue compatibility. However, these treatments were applied on the CoCr alloy, and despite favorable reports from etched titanium surfaces, future studies may investigate the interaction between soft tissue and different CoCr surfaces.

Several methods have been proposed to evaluate the implant-abutment interface fit.[34] In the present study, the direct view under SEM was used. This cross-sectional analysis allows for a more comprehensive observation of adaptation along the implant-abutment interface. However, other studies should access the influence of this internal fit on screw loosening or other prosthetic complications.

CONCLUSIONS

Within the limitations of this study, it was concluded that acid bathing should be used, instead of blasting, to remove the oxide layer and to produce a better fit and smoother surface on overcast UCLA abutments.

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