Measurement of the dimensions and abutment rotational freedom of gold-machined 3i UCLA-type abutments in the as-received condition, after casting with a noble metal alloy and porcelain firing

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Statement of problem. Laboratory processing of implant-supported prostheses may alter the surface of the abutment in contact with the implant head and thus the interface fit.
Purpose. This study assessed changes at the implant interface of gold-machined UCLA abutments after casting and porcelain baking in the case of single-tooth restorations.
Material and methods. The depth (d) and width (w) of the hexagonal portion of the abutment, the apical diameter (D) of the abutment, and the abutment rotational freedom (R) were assessed for 30 gold-machined UCLA abutments before casting procedures (time 0), after casting with a noble metal alloy (time 1), and after the addition of porcelain (time 2) to detect any eventual fitting change in the abutments on the top of the implant hexagon.
Results. No significant differences relative to all study parameters (d, w, D, and R) were observed between times 0, 1, and 2 (P=.576).
Conclusion. The results of this investigation suggest that, if all laboratory steps are observed carefully, changes at the implant interface of gold-machined UCLA abutments do not occur. (J Prosthet Dent 2000;84:548-53.)

CLINICAL IMPLICATIONS

The risk of screw loosening in single-tooth replacements can be reduced and possibly eliminated if all laboratory steps are observed carefully.

The fit between the implant and the implant-anchored prosthesis has been deemed a significant factor in stress transfer, biologic response of the peri-implant host tissues, and mechanical complications in the prosthetic reconstruction.[1-15] Vertical and horizontal misfits apply loads to the various restorative components, the implant and bone,[16] and can result in loosening of the prosthetic-retaining screws, fracture and/or locking of the abutment-retaining screws, possible microfractures of bone, zones of partial ischemia, crestal bone loss, and loss of osseointegration.[17]

The clinical and laboratory procedures used in the fabrication of implant-supported prostheses may contribute to a positional distortion of the machined abutment relative to the implant head. Despite various prosthetic and technical improvements on impression methods, master cast transference and indexing, and framework and final prosthesis fabrication, the prosthodontist is frequently faced with unstable screw joints, especially in partially edentulous and single-tooth applications.[9,18,19] In single-tooth restorations, a widely used solution is the UCLA abutment. This abutment is designed to directly engage the implant and thus allows the prosthodontist to extend the porcelain subgingivally in areas with extremely limited gingival tissue height.[20,21] The subgingival placement of the restoration not only improves esthetics but also helps in situations with interocclusal distance limitations.[20,22] In recent studies, the amount of freedom between the implant hexagonal extension and the UCLA abutment counterpart has been evaluated, and a direct correlation has been established between the hexagonal misfit of UCLA abutments and screw-joint loosening.[1-3] 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.[23,24] These manipulation processes,

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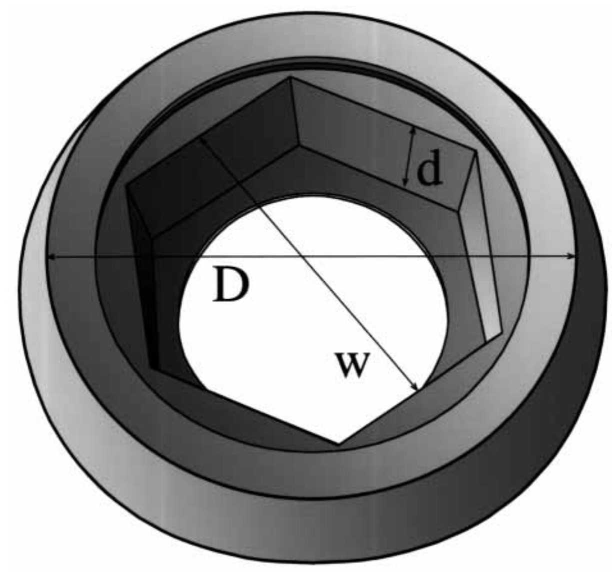

Fig. 1. Schematic representation of implant-abutment contact surface of UCLA abutment illustrating 3 parameters examined in study: depth (*d*) of internal hexagon, flat-to-flat dimension (*w*) for opposing surfaces of hexagon, and apical diameter (*D*) of abutment.

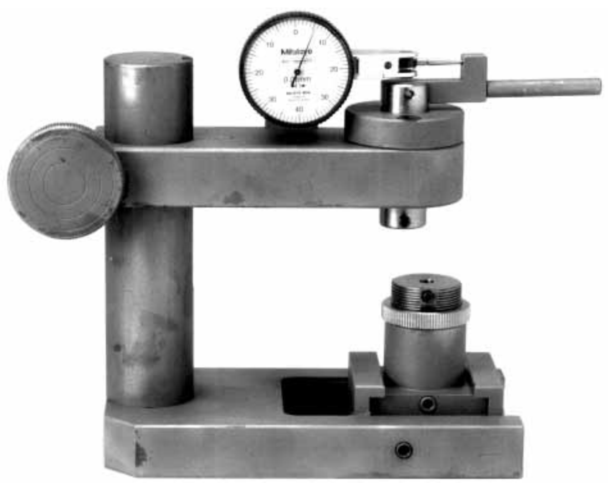

Fig. 2. Custom-made apparatus used to assess rotational freedom at implant-abutment interface.

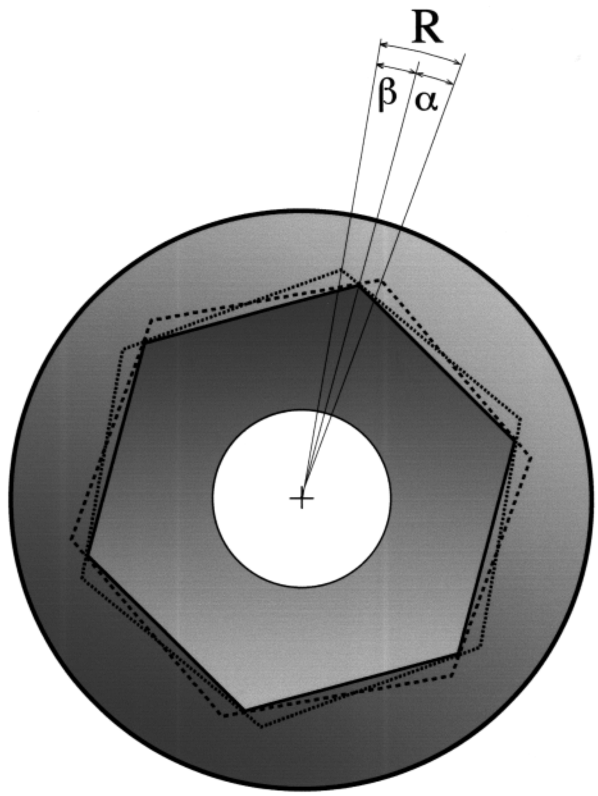

Fig. 3. Diagram illustrating rotational freedom (*R*) between implant hexagonal extension and UCLA abutment counterpart. *R* represents difference between clockwise (*α*) and counterclockwise (*β*) rotation of needle pointer attached to UCLA abutment collar.

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-UCLA cast abutment interface.

The following study was undertaken to assess changes at the implant interface after casting of a noble metal alloy and the application of porcelain to gold-machined UCLA abutments manufactured by 3i (Implant Innovations, Palm Beach Gardens, Fla.). Characterization of the changes was achieved by comparing the following measurements before casting, after casting, and finally, after porcelain baking: (1) depth and width of the hexagonal portion of the UCLA abutment, (2) apical diameter of the UCLA abutment, and (3) rotational freedom between the implant hexagonal extension and the UCLA abutment hexagonal counterpart.

MATERIAL AND METHODS

Thirty gold-machined UCLA abutments (SGUCG1, 3i) were used. As reported by the manufacturer, the UCLA abutment has a melting range of 1400°C to 1490°C and a coefficient of thermal expansion (CTE) of 13×10^{-6}/°C at 500°C. The following measurements were assessed for all abutments before casting procedures (time 0):

1. Depth (d) of the hexagonal portion of the UCLA abutment and width (w) of the internal hexagon from flat-to-flat for all 3 opposing surfaces. A mean of the 3 pairs of flats was determined[1] (Fig. 1). The measurements were carried out with a digital micrometer (Model 293, Mitutoyo, Tokyo, Japan) to the nearest micrometer.

Table I. Composition and properties of casting alloy (Esteticor Plus)

Composition	Au: 45.0%		Ga: 1.4%
	Pd: 38.9%		Sn: 0.5%
	Ag: 5.0%		Cu: 0.4%
	In: 8.6%		Ru: 0.2%
Physical properties	Melting range		1195°C-1285°C
	Density		13.8 g/cm^3
	Modulus of elasticity		112 GPa
	Coefficient of thermal expansion		14.2×10^{-6}/°C
		Melted	After firing of ceramics
Mechanical properties	Vickers hardness	245	250
	Yield strength	550 MPa	580 MPa
	Elongation	18.5%	23.5%

Table II. Firing conditions and thermal expansion characteristics of porcelain (Noritake EX-3)

Initial temperature	600°C
Temperature increase	45°C/min
Final temperature	930°C
Coefficient of thermal expansion (slow cooling)	+0.006%
Coefficient of thermal expansion (firing)	–0.005%

2. Apical diameter (D) of the UCLA abutment (Fig. 1).

3. Rotational freedom (R) between the implant hexagonal extension and the UCLA abutment counterpart. This rotational movement was measured with a custom-made apparatus similar to that described by Binon[1] (Fig. 2).

In summary, a standard threaded 3.75 × 10-mm implant (II310, 3i) was secured in the table base of the apparatus with a set screw; the abutment was seated on the implant and secured with the abutment screw that permitted rotation of the abutment. The clockwise and counterclockwise rotation of the needle pointer attached to the abutment collar was measured in minutes, and the difference between the 2 values was recorded as the amount of rotational freedom (Fig. 3).

Casting procedures

Thirty standard external hexagon analogs (ILA20, 3i) were embedded in sample cups with Sampl-kwick resin (Buehler, Lake Bluff, Ill.) and allowed to polymerize overnight. Subsequently, the UCLA abutments were screwed on top of the analogs using waxing posts; wax was added directly to the abutments following standard waxing procedures. A preformed resin mold was used to achieve an identical wax pattern for all abutments. The bulk of wax corresponded to an average-sized central incisor aligned with the long axis of the implant. The waxed cylinders were then invested in a carbon-free, phosphate-bonded investment (Ceramicor, Cendres & Métaux SA, Biel-Bienne, France) and cast using a noble alloy (Esteticor Plus, Cendres & Métaux SA) (Table I).

Postcasting measurements

Castings were allowed to bench cool and, subsequently, were divested and cleaned with air abrasion. The abovementioned measurements (d, w, D, and R) were repeated for all cast abutments (time 1).

Porcelain baking procedures and postbaking measurements

In all 30 specimens, porcelain (Noritake EX-3, Noritake Co, Nagoya, Japan) (Table II) was applied in layers to the cast abutments, carved, and then baked according to the recommendations of the manufacturer. Care was taken during porcelain addition to standardize the bulk of added material, keeping it at a thickness of 1 mm throughout the cast surface. Subsequently, measurements d, w, D, and R were repeated for the finished porcelain-fused-to-metal crowns (time 2).

Statistical analysis

Measurements d, w, D, and R were compared at times 0, 1, and 2. The mean changes between time 0 and time 1 (T0-T1), time 1 and time 2 (T1-T2), and time 0 and time 2 (T0-T2) were calculated for each parameter. The quantitative differences between time groups were assessed using multivariate analysis of variance (MANOVA) (Instat for Macintosh, GraphPad Software, Mountain View, Calif.). Statistical testing was carried out at the 5% significance level.

RESULTS

Table III shows the changes relative to measurements d, w, D, and R through the laboratory phases (times 0, 1, and 2). The mean values of the depth (d) of the hexagonal portion of the UCLA abutment were

Table III. Data relative to the measurements d, w, D, and R throughout the laboratory phases (times 0, 1, and 2)

	Mean	Minimum	Maximum	SD
As-received (time 0)				
Depth (d) (mm)	0.620	0.618	0.625	0.001
Width (w) (mm)	2.712	2.680	2.740	0.014
Diameter (D) (mm)	4.408	4.380	4.430	0.009
Rotational freedom (R) (minutes)	6.033	5.700	6.200	1.47
After casting (time 1)				
Depth (d) (mm)	0.621	0.618	0.625	0.001
Width (w) (mm)	2.710	2.680	2.750	0.16
Diameter (D) (mm)	4.407	4.380	4.420	0.10
Rotational freedom (R) (minutes)	6.037	5.600	6.200	1.75
After porcelain baking (time 2)				
Depth (d) (mm)	0.620	0.618	0.625	0.002
Width (w) (mm)	2.711	2.690	2.740	0.14
Diameter (D) (mm)	4.409	4.380	4.430	0.11
Rotational freedom (R) (minutes)	6.068	5.800	6.200	1.36

0.620 ± 0.001 mm before casting (time 0), 0.621 ± 0.001 mm after casting (time 1), and 0.620 ± 0.002 mm after porcelain baking (time 3). The recorded mean widths (w) of the internal abutment hexagon were 2.712 ± 0.014 mm, 2.710 ± 0.016 mm, and 2.711 ± 0.014 mm at times 0, 1, and 2, respectively. The corresponding mean values of the apical diameter (D) of the UCLA abutment were 4.408 ± 0.009 mm, 4.407 ± 0.010 mm, and 4.409 ± 0.011 mm. A mean rotational freedom of 60.33 ± 1.47 minutes was found between the matching hexagonal components before casting. The (R) measurements obtained at times 1 and 2 showed slightly larger values (60.37 ± 1.75 minutes and 60.68 ± 1.36 minutes, respectively). No significant differences relative to all study parameters (d, w, D, and R) were found between times 0, 1, and 2 (P=.576).

DISCUSSION

This study assessed changes at the implant hexagon interface of gold-machined UCLA abutments after casting with a noble metal alloy and the application of porcelain to the metal structure in the case of single-tooth replacements. The results demonstrated that the original fit of the 3i UCLA abutment is not significantly altered during the laboratory processes of casting and porcelain baking. In single-tooth restorations, the adaptation of various abutments to implants before, during, and after laboratory processing has been evaluated in a limited number of studies. Byrne et al[4] assessed the vertical adaptation of machined, castable, and laboratory-modified machined abutments to implants at 2 sites: the abutment-implant interface and screw-to-screw seat. Six combinations of abutments and implants were studied. The authors concluded that casting with gold-palladium alloy and porcelain baking had no effect on the vertical adaptation of the machined UCLA abutments (3i) joined to 3i implants. However, the 3i-machined UCLA abutments had fewer areas of contact with screws when subjected to casting and porcelain firing cycles. The authors related this finding to heat-induced stress release within the premachined abutments during the procedures or distortion introduced by contraction of the surrounding casting; the significance of this finding needs to be further investigated.

Other studies assessed the horizontal adaptation of different abutments to selected implants by evaluating the rotational freedom of the abutment itself on the implant hexagon.[2,3] These studies demonstrated a direct correlation between hexagonal misfit and screw-joint loosening and indicated that a rotational misfit under 2 degrees provides the most stable and predictable screw joint. Similar conclusions were reported by Jörnéus et al,[5] who concluded that screw joints could be made more resistive to screw loosening by the elimination of rotational misfit. In the current study, the mean original rotational freedom of the as-received machined UCLA abutment was 60.33 ± 1.47 minutes. Casting with low-fusing, high-palladium alloy and subsequently adding porcelain yielded minor changes in the rotational freedom of the abutments, keeping the rotation under 2 degrees. The result was less preload loss, greater joint stiffness, and consequently, a lower incidence of loose abutment screws.[2,3]

The biologic implications of misfit have been investigated mostly in multiple implant rehabilitations.[6-10] The data presented in these studies did not establish a significant correlation between vertical misfit and marginal bone resorption or loss of osseointegration. In single-tooth implant restorations, the biologic consequences of less-than-optimal fit in the vertical and horizontal dimensions have not been investigated. However, at the level of the peri-implant soft tissues, misfit in subgingival locations, as in the case of UCLA abutments, may result in bacterial aggregation with subsequent peri-implant inflammation.

Verifying the horizontal and vertical fit of a UCLA casting directly to the implant shoulder at the level of the osseous crest in a clinical setting is difficult; the casting cannot be inspected visually or manually, adequately checked with an explorer, or even assessed with radiographs because minor discrepancies are not discernible.[20] The application of disclosing media and other materials[11] can be difficult in subgingival locations and unreliable for rotational freedom evaluation. The use of the Periotest method[12-14] is still experimental, and its validity and specificity in clinical conditions still must be investigated. Although the rotational freedom of restorations using UCLA abutments can be measured in a laboratory setting using devices such as those introduced by Binon[1] or those used in this study, the reproduction of these measurements in clinical conditions may be more difficult. In the absence of simple and specific clinical fit evaluation methods, it is recommended that the clinician: (1) use implant/abutment combinations that have demonstrated good original fit in quantitative research tests, and (2) apply laboratory materials and techniques[15] that do not introduce additional significant discrepancies at the implant-abutment interface.

Selecting the correct combination of the gold alloy of the UCLA abutment and the casting alloy is often directed by experience from procedures commonly applied in traditional cast crowns and fixed partial dentures and in the nondental industry. This selection must balance the requirements of compatibility, structural integrity after laboratory procedures, corrosion resistance, strength, and hardness.[24,25] The high-fusing, gold-palladium casting alloy selected for this study is widely used by commercial dental laboratories and fulfills the requirements recommended by the UCLA abutment manufacturer. Currently, there are data available for neither the cast interface characteristics for this type of alloy nor the corrosion and galvanic response in the casting against the titanium implant.

CONCLUSIONS

This study suggests that premachined 3i UCLA abutments subjected to casting with a high-fusing, gold-palladium alloy and subsequently to porcelain baking do not demonstrate any significant alteration of the original measurements or rotational freedom of the interface surface of the abutment. These results may have both biologic and mechanical implications; however, controlled trials are needed to investigate the clinical significance of these findings in cases of single-implant prostheses. 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.

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Noteworthy Abstracts of the Current Literature

Complete dentures: An introduction (part 1)
McCord JF, Grant AA. *Br Dent J* 2000*;188:373-4.*

Purpose. In this series of articles, the authors present current changes in complete denture prosthodontics as prescribed in the United Kingdom. The articles are intended to serve as a chair-side guide for individuals interested in complete dentures.

Discussion. Over the past 30 years, worldwide surveys of edentulousnesss have indicated a steady decline in the number of adults who are completely edentulous. In the United Kingdom, the percentage of adults who are edentulous fell from 30% in 1978 to 21% in 1998. This statistic is complicated by 4 factors. First, a significant number of practitioners have become disengaged from the national health service; therefore, many of the dentures made go unreported. Second, many denture wearers who were examined on routine dental visits required replacement dentures, although the patients themselves did not feel the need to acquire these replacements. This factor indicates a potentially large reservoir of unmet need in the UK population. Third, there has been a reduction in the teaching of complete denture prosthodontics and in minimum requirements of patients treated with removable prostheses; both factors have resulted in graduates who are less included and/or able to treat the edentulous population satisfactorily. Fourth, patients who are edentulous are becoming more demanding because of their oral conditions or psychological problems related to dealing with dentures. The authors state that there is also a perception among practitioners that complete dentures are less important than other areas of restorative dentistry. When surveys of articles from 3 leading journals—the *British Dental Journal*, *Journal of the American Dental Association*, and *Journal of Prosthetic Dentistry*—are tallied, it is found that the percentage of articles devoted to complete dentures has fallen from 30% to less than 10% over the past 30 years. 9 References. —*RP Renner*