Evaluation of Gold-Machined UCLA-type Abutments and CAD/CAM Titanium Abutments with Hexagonal External Connection and with Internal Connection

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Purpose: *The purpose of this study was to assess the precision at the implant interface of gold-machined UCLA-type abutments and computer-assisted design and manufacture (CAD/CAM) titanium abutments with both external-hexagonal connection and internal-hexagonal connection.* ***Materials and Methods:*** *Fifteen gold-machined UCLA-type abutments with external-hexagonal connection, 15 gold-machined UCLA-type abutments with internal-hexagonal connection, 15 CAD/CAM titanium abutments with external-hexagonal connection, and 15 CAD/CAM titanium abutments with internal-hexagonal connection were produced. The rotational freedom of all the abutments was assessed to detect the precision of fit of each abutment on the top of the implant platform. Measurements of rotational freedom were compared among groups. The quantitative differences among groups were assessed using 1-way analysis of variance (α = .05).* ***Results:*** *Significant differences relative to rotational freedom were not found among the 4 groups (P > .19).* ***Conclusion:*** *Both types of abutments (gold-machined UCLA-type and CAD/CAM titanium) consistently showed 1 degree of rotational freedom between the implant and abutment in both cases of external-hexagonal connection and internal-hexagonal connection.* INT J ORAL MAXILLOFAC IMPLANTS 2008;23:247–252

Key words: *CAD/CAM titanium abutments, gold-machined UCLA-type abutments, hexagonal external connection, internal connection, single implant-cemented restorations*

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, implant, and bone[16] and can result in loosening of the prosthetic retaining screws, fracture and/or locking of the abutment-retaining screws, microfracture of bone, zones of partial ischemia, crestal bone loss, and loss of osseointegration.[17] To avoid mechanical and biological complications, the prosthodontist should use prosthetic components with stable screw joints, especially in partially edentulous and single-tooth applications. Some studies[2,3] have demonstrated a direct correlation between hexagonal misfit and screw joint loosening and indicated that a rotational misfit under 2 degrees would provide the most stable and predictable screw joint. Similar conclusions were drawn by Jörnéus et al,[5] who concluded that screw joints could be made more resistant to screw loosening by elimination of rotational misfit.

Single-tooth replacement with implant-supported cemented crowns has become a routine matter at many clinics. Various studies have reported on the predictability of single-implant restorations.[18–24] Some authors still stress the importance of maintaining the retrievability of cement-retained implant restorations, and they suggest the use of a tempo-

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rary cement.[25] However, should an abutment screw loosen or any repair become necessary, the restoration may be destroyed during the removal procedure if the cement seal cannot be broken easily.[26] The introduction into the market of components that need infrequent abutment screw tightening[27] has reduced the need to retrieve cement-retained implant restorations. Prosthodontic reconstruction with cement-retained implant-supported single-tooth crowns may involve abutments made from several materials directly connected to endosseous dental implants made of titanium. In single-tooth restorations, a widely used option is the UCLA abutment.[28–30] This abutment is designed to engage the implant directly. It is usually cast in gold alloys.[27] Some studies evaluated the amount of freedom between the implant hexagonal extension and the UCLA abutment counterpart, 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.[31,32] The treatment of the metal results in alteration of the mechanical properties of the metal, with possible heat softening of the metal. These manipulation processes, in addition to porcelain application, may alter the abutment surfaces in contact with the implant and may lead to changes in the original horizontal fit at the implant-abutment interface. In addition, the manipulation of the material when metals are cast to the UCLA abutment could alter the surface of the material as investment and could roughen or modify the mating surface of the retentive screw and the abutment (the screw seat). This could alter the friction encountered during screw tightening, which could result in diminished preload.[32] In a previous study[27] limited to gold-machined UCLA-type abutments with an external hexagonal connection, it was shown that premachined UCLA abutments subjected to casting with a high-fusing gold-palladium alloy and subsequently to porcelain application did not demonstrate any significant alteration of the original measurements or rotational freedom of the interface surface of the abutment.

Recently 3i (Biomet/3i, Palm Beach Gardens, FL) developed the Encode system based on computer-assisted design and manufacture (CAD/CAM) technology.[33] These CAD/CAM titanium abutments can be made with an external hexagonal connection or with an internal connection similar to gold-machined UCLA-type abutments. No data have been published yet concerning the precision of these CAD/CAM titanium abutments.

The following study was undertaken to assess the rotational freedom between the implant and the abutment for gold-machined UCLA-type abutments, made through laboratory procedures by a dental technician, and for Encode titanium abutments, made with CAD/CAM procedures, in combination with either hexagonal external-connection or internal-connection implants.

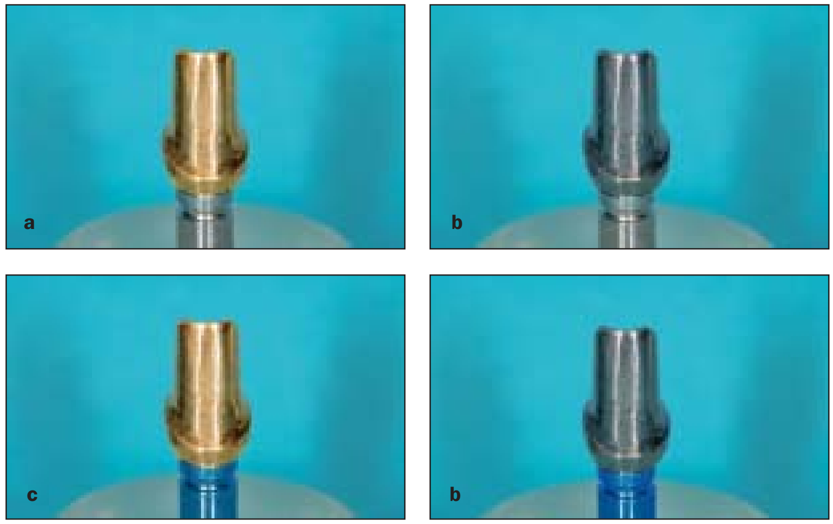
MATERIALS AND METHODS

Abutment Preparation Procedures

Thirty standard external hexagon laboratory analogs (ILA20, Biomet/3i, Palm Beach Gardens, FL) and thirty Certain laboratory analogs (IILA20, Biomet/3i) were embedded in sample cups with Sampl-kwick resin (Buehler, Lake Bluff, IL) and allowed to polymerize overnight. The 30 specimens with standard external hexagon analogs (Group A) and the 30 specimens with Certain laboratory analogs (Group B) were respectively divided in 2 groups (1 and 2) of 15 cylinders each according to a randomization plan.[34]

Group A1. Fifteen gold-machined UCLA abutments (SGUCG1, Biomet/3i) were used. According to the manufacturer, the UCLA abutment has a melting range of 1400°C to 1490°C and a coefficient of thermal expansion of 13×10^{-6}/°C at 500°C. 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 (Duralay; Reliance Dental Manufacturing, Worth, IL) 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, Biel-Bienne, France) and cast using a noble alloy (Esteticor Plus, Cendres & Métaux; Table 1). Castings were allowed to bench cool and were subsequently divested and cleaned with air abrasion (Fig 1a).

Group A2. A healing abutment (EHA444, Biomet/3i) was placed on top of each analog. The healing abutments had codes embedded in the occlusal surfaces. Fifteen separate impressions in light-bodied polyether[35,36] (Permadyne Penta L; 3M ESPE, Seefeld, Germany) were made of each healing abutment according to the manufacturer's directions; a copper ring (no. 26, E. Hahnenkratt, Königsbach-Stein, Germany) was used to contain the material. The impression material was machine-mixed (Pentamix; 3M ESPE), and the material was meticulously syringed around the healing abutment to ensure a clear impression of all occlusal markings and the entire cir-



Figs 1a to 1d An abutment from each group in the testing apparatus: group A1 (gold-machined UCLA-type abutments with hexagonal external connection), group A2 (CAD/CAM titanium abutments with hexagonal external connection), group B1 (gold-machined UCLA-type abutments with internal connection), and group B2 (CAD/CAM titanium abutments with internal connection). The abuments were prepared to achieve a shape comparable to that corresponding to an average-sized central incisor aligned with the long axis of the implant.

cumference of the healing abutment. An ADA Type IV yellow die stone (New Fujirock; GC Corporation, Tokyo, Japan) was used in accordance with the manufacturer's instructions to pour all the impressions. For proper scanning, all casts provided visibility of the healing abutment; all showed a defect-free occlusal surface. All casts were sent to the production facility (Biomet/3i) and then scanned with a laser optical scanner. A resin mold (Duralay, Reliance Dental) was also sent and used to determine the shape of all abutments produced. The size of the mold corresponded to an average-sized central incisor aligned with the long axis of the implant, as for all other groups. The final abutments were then milled from a solid titanium blank. After final polishing, the 15 hexagonal external abutments were sent back for final measurements of the precision at the implant interface (Fig 1b).

Group B1. Fifteen gold-machined UCLA abutments (IGUCA1C, Biomet/3i) for internal-hexagon implants were made. The same laboratory procedures as for group A1 were followed (Fig 1c).

Group B2. A healing abutment (IEHA444, Biomet/3i) was placed on top of each analog. The same manufacturing procedures used for group A2 were followed. Fifteen titanium abutments were produced for internal-hexagon implants (Fig 1d).

Rotational freedom between the implant (external and internal connection) and the abutment counterpart was measured using a custom-made apparatus similar to that described by Binon[1] (Fig 2). This apparatus has been used in previous research.[27,37,38] For groups A1 and A2, an Osseotite 3.75 × 10-mm implant (OSS410, Biomet/3i) was used. A Certain 3.75 × 10-mm implant (IOSS410, Biomet/3i) was used for groups B1 and B2. The implant 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 in a manner that still 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 degree of rotational freedom. Rotational freedom was assessed for all UCLA abutments before casting procedures to evaluate fit in an unaltered state.

Statistical Analysis

Measurements of rotational freedom were compared between groups. Mean, minimum, maximum, and standard deviation were calculated for each group. The Bartlett test was used to test the homogeneity of variances between groups ($\alpha = .05$), and the Kolmogorov-Smirnov test was used to test the normality ($\alpha = .05$). The quantitative differences between groups were assessed using 1-way analysis of variance ($\alpha = .05$)

The homogeneity of variances and the normality of the rotational freedom between groups were checked to ensure that analysis of variance had been used correctly.

Fig 2 Custom-made apparatus used to assess rotational freedom at implant-abutment interface. The needle pointer *(arrow)*, with its clockwise and counterclockwise rotation, allowed rotational freedom to be recorded.

Table 2 Data Relative to Rotational Freedom (minutes) for Both UCLA Abutment Groups Before Casting Procedures

Group	Mean	Minimum	Maximum	SD
A1	60.73	57.00	62.00	1.47
B1	60.58	59.20	61.55	1.21

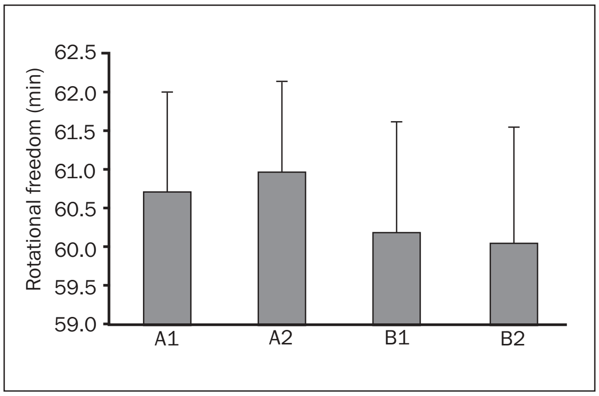


Fig 3 Mean rotational freedom in minutes for each group; error bar indicates standard deviation.

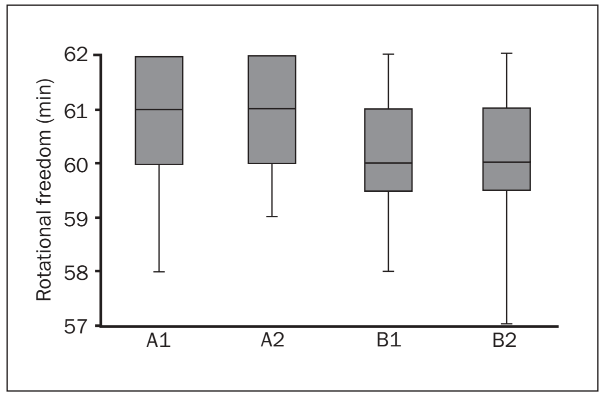


Fig 4 Box-and-whiskers plot comparing rotational freedom in minutes for each group. The top and bottom of each box show the 75th and 25th percentiles. Whiskers depict maximum and minimum values. The horizontal line inside boxes indicates the median value.

Table 3 Data Relative to Rotational Freedom (minutes) for Each Group

Group	Mean	Minimum	Maximum	SD
A1 (Uex)	60.33	58.00	62.00	1.28
A2 (Uint)	61.00	59.00	62.00	1.13
B1 (CCex)	60.20	58.00	62.00	1.42
B2 (CCint)	60.06	57.00	62.00	1.49

RESULTS

Table 2 shows the rotational freedom assessed for all UCLA abutments (groups A1 and B1) before casting procedures. Table 3 shows mean, minimum, maximum, and standard deviation relative to rotational freedom after casting procedures for groups A1 and B1 and after CAD/CAM procedures for groups A2 and B2. In groups A1 and B1, no differences in rotational freedom were detected before casting and after casting with a high-fusing gold palladium alloy.

Means and standard deviations are also plotted in Figure 3. The distribution of rotational freedom for each group is shown in Figure 4: It seemed slightly more symmetric for groups B1 and B2 (the internal-hexagon connection) .

Rotational freedom was slightly smaller for the internal-hexagon groups (Table 3, Fig 3). The Bartlett test was performed, and the homogeneity of variance was accepted for rotational freedom between each group ($P > .7$). The Kolmogorov-Smirnov test revealed that the normality of rotational freedom was accepted for groups A1 ($P > .3$), for A2 ($P > .19$), B1 ($P > .70$), and B2 ($P > .45$). One-way ANOVA did not reveal quantitative differences of mean rotational freedom between the 4 different groups ($P > .19$), in contrast with the visual impression.

DISCUSSION

This study was undertaken to assess the rotational freedom between the implant platform and the abutment counterpart for 2 types of abutments. For the gold-machined UCLA abutments, the interface was made by the manufacturer and then the technician cast metal to the abutment in the laboratory. The second abutment type was made of titanium and based on CAD/CAM technology. Both types of abutments were made for both external-hexagonal-connection implants and internal-connection implants.

The premachined UCLA abutments, although subjected to casting with a high-fusing, gold-palladium alloy, did not demonstrate any significant alteration from the original rotational freedom of the abutment in the unaltered state. This confirmed the results of a previous study limited to external-hexagonal-connection implants.[27]

For all 4 groups of abutments evaluated in this study, the rotational value was consistently ≤ 1 degree. The absence of any statistical difference between the 2 types of abutments (gold-machined UCLA abutments after casting and titanium CAD/CAM abutments) on 2 different connection systems (external hexagonal and internal hexagonal) may result in similar clinical behavior. However, in clinical situations implant abutments are subjected to different types of loads (axial, nonaxial, asymmetric). The differences in behavior between these 2 types of abutment-implant connection in real clinical functioning have not been properly studied yet.

In single-tooth restorations, the adaptation of various abutments to implants has been evaluated in a limited number of studies. Some laboratory studies have 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] A direct correlation between hexagonal misfit and screw-joint loosening has been demonstrated in the laboratory: A rotational misfit under 2 degrees was considered the most stable and predictable screw joint for external hexagonal connection. Similar conclusions were drawn by Jörnéus et al,[5] who concluded that screw joints could be made more resistant to screw loosening by elimination of rotational misfit. Although it should be underlined that the clinical application of these in vitro results did not always demonstrate similar outcomes, in a previous clinical retrospective review, the design change in the abutment screw resulted in highly significant improvement in screw-joint integrity.[39] The results of this clinical study seemed to stress component design as the primary factor in screw-joint maintenance compared to the importance of close mating of implant and abutment surfaces. However, at the level of peri-implant soft tissues, misfit in subgingival locations between implant and abutment may result in bacterial aggregation with subsequent peri-implant inflammation. Verification of the horizontal and vertical fit of an abutment directly to the implant shoulder at the level of the osseous crest in a clinical setting is difficult, since it cannot be visually or manually inspected, adequately checked with an explorer, or even assessed with radiographs, because minor discrepancies would not be discernible.[29] The application of disclosing media and other materials[11] can be difficult in subgingival locations and unreliable for evaluation of rotational freedom. Although the rotational freedom of restorations using the abutments can be measured in a laboratory setting by using devices such as those introduced by Binon,[1] the reproduction of these measurements in actual clinical conditions may be more difficult. In the absence of simple and specific clinical fit evaluation methods, the recommendation is to use implant-abutment combinations that have demonstrated a good original fit in research quantitative tests and to apply laboratory techniques which would not result in additional significant discrepancies at the implant-abutment interface.[15]

CONCLUSION

This study demonstrates that both types of abutments (gold-machined UCLA-type after casting and CAD/CAM titanium abutments) constantly showed 1 degree of rotational freedom between the implant and abutment in case of hexagonal external connection and internal connection.

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