An In Vitro Evaluation of ZiReal Abutments with Hexagonal Connection: In Original State and Following Abutment Preparation

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Purpose: *Laboratory processing of implant-supported prostheses may alter the surface of the abutment in contact with the implant head, with potential repercussions for the interface fit. The purpose of this study was to assess changes at the implant interface of high-strength zirconia ceramic esthetic abutments with a hexagonal connection (ZiReal; 3i/Implant Innovations, Palm Beach Gardens, FL) following abutment preparation for single-tooth restorations.* ***Materials and Methods:*** *The depth (d) and width (w) of the titanium hexagonal portion of the abutment, the apical diameter of the abutment (D), and the rotational freedom (R) of the abutment were assessed for 20 ZiReal abutments prior to preparation (time 0) and following abutment preparation (time 1) to detect any eventual change of fit of the abutment on the top of the implant hexagon.* ***Results:*** *No significant differences relative to any study parameter (d, w, D, and R) were observed between time 0 and time 1 (P = .9542).* ***Discussion and Conclusions:*** *The hexagonal misfit of the titanium machined ZiReal abutment on the implant hexagon may be implicated in screw joint loosening. The results of this report suggest that if all laboratory steps are carefully observed, changes at the implant/ZiReal abutment do not occur. The maintenance of the original features of the ZiReal abutment may reduce the risk of screw loosening.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:108–114

Key words: *abutments, dental implants, esthetics, single-tooth replacement*

Restorations in the anterior esthetic zone present significant challenges in both the surgical and prosthetic phases of implant dentistry.[1–3] Many types of implants require transmucosal abutments to retain implant restorations, and most transmucosal abutments are made of titanium or metal alloy. However, full ceramic crowns may be the ideal choice to replace natural teeth in esthetic areas. The combination of ceramics for abutment and crown would provide better translucency for the implant restoration than is obtainable with metal abutments and ceramometal crowns. Ceramic abutments and implant restorations would also minimize the gray color associated with metal components that is transmitted through the peri-implant tissues.[4]

In 1994, the first esthetic ceramic abutment of dense aluminum oxide (Al_2O_3) was introduced (CerAdapt, Nobel Biocare, Göteborg, Sweden). The problems presented by this abutment included its radioclarity at the time of radiologic examination and its fragility and weak resistance to fracture.[5–7] Some in vivo studies have tested the clinical characteristics of these esthetic abutments.[8] The results demonstrated the esthetic possibilities and the safety of single-tooth replacement when accepted treatment concepts were followed and documented components

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were used. The tested abutments were satisfactory, although the fractured CerAdapt abutments indicated that ceramic abutments were more sensitive to handling procedures than the titanium abutments. Recent studies have shown that less risky functional and esthetic results can be achieved with ceramic implant abutments.[9,10]

The introduction of zirconium oxide abutments provided new opportunities for single-tooth restorations. One recently presented solution is the ZiReal abutment (3i/Implant Innovations, Palm Beach Gardens, FL).[3] This abutment is an esthetic abutment, composed primarily of high-strength zirconia ceramic (zirconium oxide [ZrO_2]), a radiopaque material with well-documented biocompatibility, and is designed to engage the implant directly with its machined titanium base. It is meant to be laboratory prepared to meet individual requirements, and an all-ceramic crown can be cemented onto it. As with the UCLA abutment, it can be used in areas with extremely limited gingival tissue height and in situations with interocclusal distance limitations.

In implant prosthodontics, the importance of the absence of rotation at the implant-abutment interface has been highlighted by several authors.[11–13] The fit between the implant and the implant-supported prosthesis has been advocated as a significant factor in stress transfer, biologic response of the peri-implant host tissues, and mechanical complications in the prosthetic reconstruction. Vertical and horizontal misfit applies loads to the various restorative components, the implant, and the bone,[14] and can result in loosening of the prosthesis-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.[15] 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 the various improvements in impression methods, transference, indexing to the master cast, and framework and definitive prosthesis fabrication, the prosthodontist is frequently faced with unstable screw joints, especially in partially edentulous and single-tooth applications.[16–18] Lack of precision may lead to micromovement, which can strip the implant hex. The amount of freedom between the implant hexagonal extension and the UCLA abutment counterpart has been evaluated in recent studies,[11–13] and a direct correlation has been established between the hexagonal misfit of UCLA abutments and screw joint loosening. When metal alloys are cast to a machined gold UCLA abutment, the latter is exposed to the range and levels of temperatures required in the burnout and casting procedure. These processes, in addition to porcelain baking, could alter the abutment surfaces contacting the implant and lead to changes in the original horizontal fit at the implant–UCLA cast abutment interface. In a previous study,[19] it was shown that premachined 3i UCLA abutments subjected to casting with a high-fusing gold-palladium alloy and subsequently to porcelain baking did not demonstrate any significant alteration of the original measurements or rotational freedom of the interface surface of the abutment. Little or no data have been published concerning zirconium abutments with a hexagonal connection. Following tests performed by the manufacturer, the rotational freedom of the ZiReal abutment demonstrated an implant/abutment interface rotational movement no greater than 3 degrees prior to the milling phase.

The following study was undertaken to assess changes at the implant interface following abutment preparation of zirconia abutments with a hexagonal connection. Characterization of changes was achieved by comparing the following measurements both before and after preparation of the abutment:

- Depth and width of the titanium hexagonal portion of the abutment
- Apical diameter of the abutment
- Rotational freedom between the implant hexagonal extension and the abutment hexagonal counterpart

MATERIALS AND METHODS

Twenty ZiReal abutments with hexagonal connection (3i/Implant Innovations) were used. This abutment may be used for the 4.1-mm implant platform size; the post is 5.0 mm wide and the collar is 4.0 mm high. According to the manufacturer's data, the ZiReal abutment is made of stabilized zirconia, and the composition of the ceramic blank abutments consists of Vita In-Ceram Zirconia (VITA Zahnfabrik, H. Rauter, Bad Säckingen, Germany), which combines tetragonal 30% ZrO_2 with particles smaller than 3 µm in width and Al_2O_3 with particles smaller than 5 µm. Zirconia has a natural ability to transmit light and has characteristics similar to those of natural enamel. The resistance to fracture of these abutments is beyond 900 MPa, while the International Organization for Standardization (ISO) minimum required is 250 MPa. In addition, the fracture toughness of zirconia is 7 MPa, whereas most Al_2O_3 ceramics vary from 4 to 5 MPa.

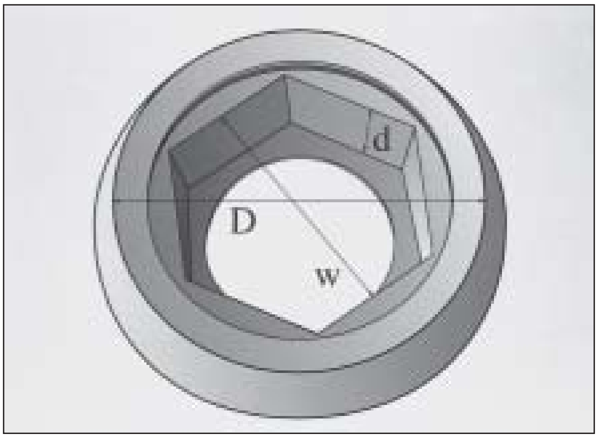

Fig 1 Schematic representation of implant-abutment contact surface of ZiReal abutment illustrating 3 parameters examined: depth of the internal hexagon *(d)*, the distance between opposing surfaces of the hexagon, ie, the width *(w)*, and apical diameter of the abutment *(D)*.

Fig 2 Custom-made apparatus used to assess rotational freedom at the implant-abutment interface. The needle pointer *(arrow)* with its clockwise and counterclockwise rotation enabled the recording of rotational freedom *(R)*.

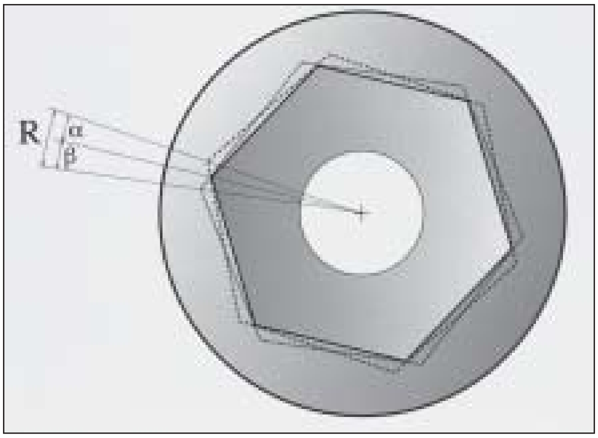

Fig 3 Diagram illustrating rotational freedom (R) between the implant hexagonal extension and the ZiReal abutment counterpart. R represents the difference between clockwise (α) and counterclockwise (β).

The following parameters were assessed for all abutments prior to preparation procedures (time 0):

- Depth (d) of the titanium hexagonal portion of the 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[11] (Fig 1). The measurements were carried out using a digital micrometer (Mitutoyo, Tokyo, Japan) to the nearest micrometer.
- Apical diameter (D) of the abutment (Fig 1)
- Rotational freedom (R) between the implant hexagonal extension and the abutment counterpart; this rotational movement was measured using a custom-made apparatus similar to that described by Binon[11] (Fig 2) and used in previous research.[19] To summarize, a standard threaded 3.75 × 10-mm implant (3i/Implant Innovations) was secured in the table base of the apparatus with a set screw, and the abutment was seated on the implant and secured with the abutment screw in a manner that still permitted the 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 (Fig 3).

Abutment Preparation Procedures

Twenty standard external-hexagon analogs (3i/Implant Innovations) were embedded in sample cups with Sampl-kwick resin (Buehler, Lake Bluff, IL) and allowed to polymerize overnight. Subsequently, ZiReal abutments were screwed on top of the analogs using lab screws (Square Try-in Screws, 3i/Implant Innovations). The abutments were prepared with diamond burs (Komet 8855 025 and 6855 025, Gebr Brasseler, Lemgo, Germany) mounted on a high-speed handpiece for 15 minutes under abundant irrigation[20] to achieve a shape comparable to that corresponding to an average-sized central incisor aligned with the long axis of the implant (Fig 4). The abundant irrigation prevented an excessive increase in the temperature of the zirconia material; it also allowed application of a delicate pressure of the bur on the abutment during the preparation phase without transferring deleterious vibration to the titanium hexagonal portion of the ZiReal abutment to maintain its precise characteristic. A silicone mold was fabricated and used to control the preparation of all abutments.

Postpreparation Measurements

The previously described measurements (d, w, D, and R) were repeated for all prepared abutments after preparation (time 1).

Statistical Analysis

Measurements d, w, D, and R were compared at times 0 and 1. Means and standard deviations (SDs) were calculated for each parameter. The Bartlett test was used to test the homogeneity of variances between times 0 and 1 for each parameter ($P < .05$). The quantitative differences ($P < .05$) between time groups were assessed using multivariate analysis of variance (MANOVA).

Fig 4 Testing apparatus. The abutment was prepared with diamond burs to achieve a shape comparable to that of an average-sized maxillary central incisor aligned with the long axis of the implant.

RESULTS

Relative to intraoperator variability, standard deviations of the 10 repeated measurements for the abutments selected at times 0 and 1 for d, w, D, and R, are shown in Table 1. The small standard deviations indicate the acceptable reliability of the measurement method.

Table 2 shows the changes relative to measurements d, w, D, and R through the laboratory phases (times 0 and 1). The Bartlett test was performed, and the homogeneity of variances was accepted for d, w, D, and R between times 0 and 1, with P equal to .8112, .4263, .5764, and .3507, respectively. The distributions (and thus the variability) of each parameter are shown in Figs 5 through 8.

No significant differences relative to the MANOVA for d, w, D, or R were found between times 0 and 1 ($P = .9542$).

All results related to the parameters d, w, and D were similar to those shown in a previous study of gold machined UCLA abutments following casting of a noble metal alloy and the application of porcelain.[19] The gold machined UCLA abutments showed minor R compared to the ZiReal abutment: A mean rotational freedom of 60.33 ± 1.47 minutes was found between the matching hexagonal components before casting. The R measurements obtained after casting with a high-fusing gold-palladium alloy and after porcelain baking showed slightly larger values (60.37 ± 1.75 minutes and 60.68 ± 1.36 minutes, respectively).

Table 1 Standard Deviation, Relative to Intraoperator Variability, of the 10 Repeated Measurements in the Master Cast Selected at Times 0 and 1

	Standard deviation	
	Time 0	Time 1
Depth (d) (mm)	0.002	0.001
Width (w) (mm)	0.016	0.016
Diameter (D) (mm)	0.010	0.012
Rotational freedom (R) (min)	1.229	0.789

Table 2 Data Relative to the Measurements d, w, D, and R Throughout the Laboratory Phases

	Mean	Minimum	Maximum	SD
Time 0				
Depth (d) (mm)	0.620	0.618	0.625	0.002
Width (w) (mm)	2.712	2.680	2.740	0.014
Diameter (D) (mm)	4.408	4.380	4.430	0.010
Rotational freedom (R) (min)	120.330	117.000	122.000	1.470
Time 1				
Depth (d) (mm)	0.621	0.618	0.625	0.002
Width (w) (mm)	2.710	2.680	2.750	0.016
Diameter (D) (mm)	4.407	4.380	4.420	0.011
Rotational freedom (R) (min)	120.360	116.000	122.000	1.750

DISCUSSION

Restorations in the anterior esthetic zone present significant challenges in both the surgical and prosthetic phases of implant dentistry. The combination of ceramics for abutment and crown provides better translucency for the implant restoration than is available with metal abutments and porcelain-fused-to-metal crowns.[3,21] This would permit the elimination of problems of color and metal shining through at the peri-implant gingival level and improvement of the crucial factor influencing the esthetic outcome, which is the emergence profile of the restoration.

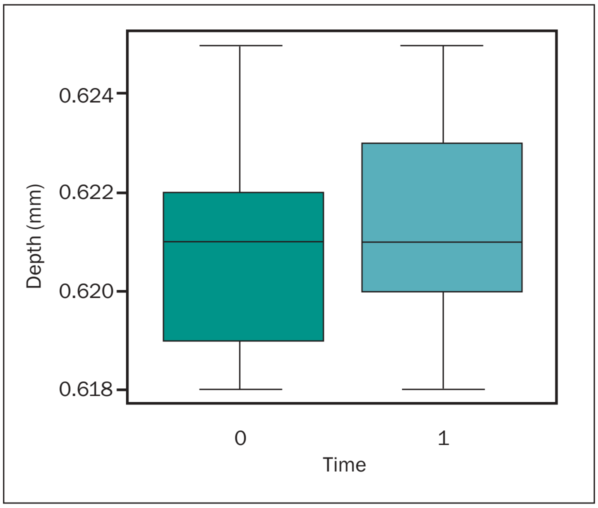

Fig 5 Box-and-whiskers plot comparing depth at times 0 and 1. Variability is homogenous between times 1 and 0 (P = .8112). For Figs 5 through 8, the tops and bottoms of the boxes indicate the 75th and 25th percentiles. The tops and bottoms of the whiskers depict maximum and minimum values. The horizontal line inside the boxes represents the median value.

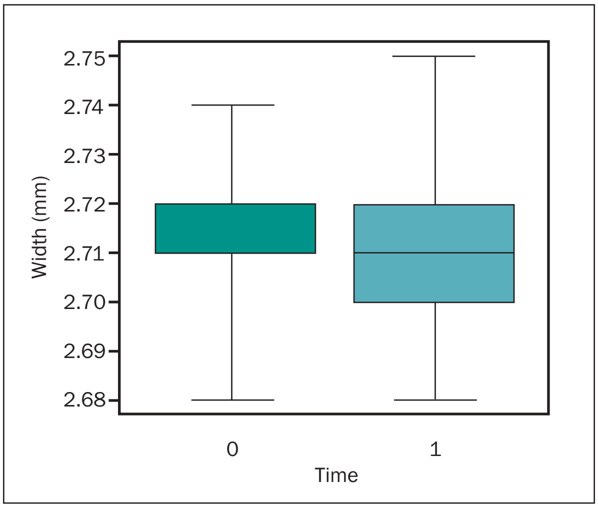

Fig 6 Box-and-whiskers plot comparing width at times 0 and 1. Variability is homogenous between times 1 and 0 (P = .4263).

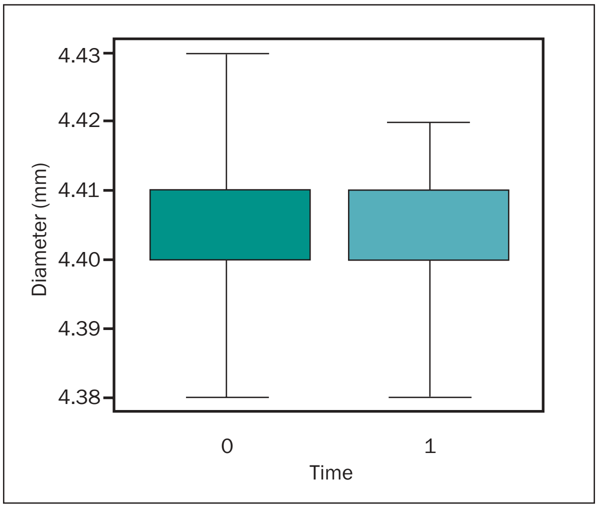

Fig 7 Box-and-whiskers plot comparing diameter at times 0 and 1. Variability is homogenous between times 1 and 0 (P = .5764).

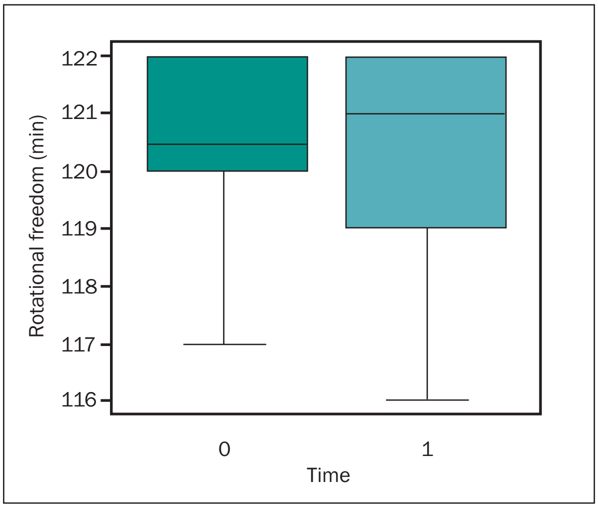

Fig 8 Box-and-whiskers plot comparing rotational freedom at times 0 and 1. Variability is homogenous between times 1 and 0 (P = .3507).

In single-tooth restorations, the adaptation of various abutments to implants before and after laboratory processing has been evaluated in a limited number of studies. Byrne and colleagues[22] assessed the vertical adaptation of machined, castable, and laboratory-modified machined abutments to implants at 2 sites: the abutment/implant interface and the 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 joined to 3i implants. However, they indicated that the machined UCLA abutments had fewer areas of contact with screws when cast onto and subjected to porcelain firing cycles. The authors related this finding to "stress release within the premachined abutments induced with heat during the procedures or distortion induced by contraction of the surrounding casting," but indicated that the significance of this finding needs to be investigated further.

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.[12,13] These studies 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 and coworkers,[23] who concluded that screw joints could be made more resistant to screw loosening by elimination of rotational misfit. Another study suggested that premachined UCLA abutments subjected to casting with a high-fusing gold-palladium alloy and subsequently to porcelain baking did not demonstrate any significant alteration from the original measurements or rotational freedom of the interface surface of the abutment.[19]

The purpose of the present study was to assess changes at the implant hexagon interface of ZiReal abutments following abutment preparation for single-tooth replacements. The results demonstrated that the original fit of an abutment was not significantly altered through laboratory processes. The abundant irrigation used during the preparation phase allowed the application of a delicate pressure on the abutments using burs without transferring deleterious shaking to the titanium hexagonal portion of the abutments, which maintained their precise characteristics. The R of the abutment was 120.33 ± 1.47 minutes at time 0 and 120.36 ± 1.75 minutes at time 1. The R of the ZiReal abutments showed larger values compared to those shown by premachined UCLA abutments.[19] In any case, the R of the ZiReal abutments was always less than the data obtained from tests performed by the manufacturer, which demonstrated an implant/abutment interface rotational movement no greater than 3 degrees.

The biologic implications of misfit have been investigated for the most part in multiple-implant restorations.[18,24–27] The data presented in these studies did not establish a significant correlation between vertical misfit and marginal bone resorption or loss of osseointegration. For 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 peri-implant soft tissues, misfit in subgingival locations, as in the case of ZiReal abutments, may result in bacterial aggregation with subsequent peri-implant inflammation.

Verification of the horizontal and vertical fit of a ZiReal 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.[28] The application of disclosing media and other materials[29] can be difficult in subgingival locations and unreliable for evaluation of rotational freedom. Although the rotational freedom of restorations using ZiReal abutments can be measured in a laboratory setting using devices such as those introduced by Binon,[11] 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 introduce additional significant discrepancies at the implant/abutment interface.[30]

CONCLUSION

This study suggests that 3i ZiReal abutments subjected to abutment preparation 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.

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