Implants with Original and Non-Original Abutment Connections

Michel Gigandet, med. dent;* Gianni Bigolin;[†] Francisco Faoro;[‡] Walter Bürgin, biomed. eng;[§] Urs Brägger, Prof. Dr. med. dent[¶]

ABSTRACT

Aim: To test *in vitro* the mechanical resistance, rotational misfit and failure mode of three original implant-abutment connections and to compare them to two connections between non-original abutments connected to one of the original implants.

Material and Methods: Three different implants with small diameters (3.3 mm for Straumann Roxolid, 3.5 mm for Nobel Biocare Replace and Astra Tech Osseospeed TX) were connected with individualized titanium abutments.

Twelve implants from each system were connected to their original abutments (Straumann CARES, Nobel Biocare Procera, Astra Tech Atlantis). Twenty-four Roxolid implants were connected with non-original abutments using CAD/ CAM procedures from the other two manufacturers (12 Nobel Biocare Procera and 12 Astra Tech Atlantis). For the critical bending test, a Zwick/Roell 1475 machine and the Xpert Zwick/Roell software were used.

Results: The rotational misfit varied when comparing the different interfaces. The use of non-original grade V titanium abutments on Roxolid implants increased the force needed for deformation. The fracture mode was different with one of the original connections.

Conclusions: Non-original abutments differ in design of the connecting surfaces and material and demonstrate higher rotational misfit. These differences may result in unexpected failure modes.

KEY WORDS: abutment connection, abutments, CAD/CAM, dental implants, ISO 14801, non-original, original, titanium grade IV, titanium grade V

INTRODUCTION

For numerous clinical situations with missing teeth, implant-supported reconstructions have emerged as the treatment of choice. Their preference over conventional prosthetic reconstructions is based to a great extent on the high percentage of implants with a non-eventful tissue integration phase and the broad range of prosthetic options without the need to prepare adjacent teeth.

The long-term successful performance of implantsupported reconstructions depends on the maintenance

DOI 10.1111/j.1708-8208.2012.00479.x

of the tissue integration and a biomechanically stable abutment-implant interface. Progress in material science and manufacturing has resulted in a reduced rate of mechanical complications related to the implantabutment interface compared to frequent events observed with older components.^{1,2}

The search for additional indications for implantsupported reconstructions led to the development of small-diameter implants manufactured from a titanium/ zirconium alloy.^{3–5} In smaller spaces and narrower ridges, an implant-supported reconstruction can therefore be provided without the need for augmentation procedures or orthodontic widening of the available space. In addition, the higher mechanical strength of the titanium/ zirconium alloy means that the risk for implant fractures associated with small-diameter implants could be minimized.^{6,7} The potential biomechanical risks by using reduced diameter implants must be compared to the costs and risks of sophisticated pretreatment procedures to achieve an ideal recipient site.

^{*}Doctoral candidate, School of Dental Medicine, University of Bern, Bern, Switzerland; [†]testing mechanic, RMS Foundation, Bettlach, Switzerland; [†]director production development, Institut Straumann, Basel, Switzerland; [§]scientific advisor, School of Dental Medicine, University of Bern, Bern, Switzerland; [§]School of Dental Medicine, University of Bern, Bern, Switzerland

Reprint requests: Prof. Urs Brägger, University of Bern, Freiburgstrasse 7, 3010 Bern, Switzerland; e-mail: urs.braegger@zmk.unibe.ch

^{© 2012} Wiley Periodicals, Inc.

Economic pressure to produce and deliver implantsupported reconstructions at a reduced price for materials may lead to the acceptance of alternative solutions involving non-original abutments (i.e., abutments made by a different manufacturer than the implant) available on the market. Limited access to equipment and reduction of investments in the dental laboratory could also result in the selection of non-original abutments. The design of screw joints such as those at the implantabutment interfaces should, however, be matched carefully because the biomechanical properties depend to a great extent on factors such as materials, tolerance, connection design, and preload.^{8–12}

The aims of this study were:

- First: To test *in vitro* the mechanical resistance of three original implant-abutment interfaces and to compare these original interfaces to two combinations between non-original abutments connected to one of the original implants.
- Second: To test the influence of geometric discrepancies at the interfaces between the implants and the original and non-original abutments by assessing the rotational misfit.
- Third: To assess and compare the failure modes.

Small-diameter implants were chosen in order to test a more high-risk condition compared to implantabutment connections of standard dimensions. The null hypothesis was that there would be no significant difference in the mechanical characteristics between the original and non-original interfaces.

MATERIALS AND METHODS

Implants and Prosthetic Components

Diameter-reduced implants from three different implant manufacturers (Straumann, Basel, Switzerland; Nobel Biocare, Kloten, Switzerland; and Astra Tech, Lausanne, Switzerland) were used.

The three different implants with small diameters (3.3 mm for Straumann Roxolid, 3.5 mm for Nobel Biocare Replace and Astra Tech Osseospeed TX) were connected with individualized CAD/CAM titanium abutments.

Twelve implants from each system were connected to their original corresponding abutment systems (12 Straumann CARES, 12 Nobel Biocare Procera, 12 Astra Tech Atlantis). In addition, 24 Roxolid implants were connected with non-original abutments using CAD/ CAM procedures from the other two manufacturers (12 Nobel Biocare Procera and 12 Astra Tech Atlantis).

The shape of the abutments accommodated an implant-supported crown to replace a lower incisor. The original abutments for group A were designed using a CAD/CAM system (CARES). The abutments for group B, C, D, and E were first designed by means of a wax-up and then produced after scanning using CAD/CAM (Procera[®] or Atlantis[®]).

The evaluated groups were as follows:

- Group A: Straumann BL NC 3.3 mm Roxolid (Institute Straumann) with titanium CARES® abutments (Institute Straumann)
- Group B: Straumann BL NC 3.3 mm Roxolid with Nobel Biocare Procera® abutments (Nobel Biocare)
- Group C: Straumann BL NC 3.3 mm Roxolid with Astra Tech Atlantis[®] abutments (Astra Tech)
- Group D: Nobel Biocare Replace Straight 3.4 NP (Nobel Biocare) with Nobel Biocare Procera[®] abutments
- Group E: Astra Tech OsseoSpeed TX 3.5S (Astra Tech) with Astra Tech Atlantis® abutments

Rotational Play

All implants were individually assembled in a holding device. A rotation measurement tool (Heidenhain PGM 349,797-07, Dr. Johannes Heidenhain GmbH, Traunreut, Germany) was attached to the corresponding abutment. The abutment was rotated anti-clockwise until a mechanical stop relative to the implant was achieved. The abutment was lifted from the implant by 0.1 mm relative to its long axis to neutralize friction fit. The rotation measurement tool was reset. Then, the measurement was taken by rotating the abutment clockwise until a mechanical stop relative to the implant was achieved. Rotational play was evaluated by means of total rotational play between two end positions.

Critical Bending Moment

The implants were embedded into a block of epoxy resin RenCast®CW 20/Ren® HY 49 (Huntsman Advanced Materials, Cambridge, UK). This material is characterized by its high resistance to compression (140 MPa) and a compressive elastic modulus of 11,000–11,500 MPa according to ISO 604. The implants were embedded to a depth of 3.0 mm \pm 0.1 mm short of the top of the implant neck in order to mimic 3 mm of loss in bone height (according to ISO 14801) (Figure 1).



Figure 1 Embedded implant-abutment specimen with the milled stainless steel cylinder. The epoxy block ended $3 \text{ mm} \pm 0.1 \text{ mm}$ short of the implant neck according to ISO 14801.

The epoxy blocks were then tightened into a stainless steel socket at 30° to the vertical plane.

The abutments were torqued according to the recommendations of each manufacturer using the original torque control ratchets (35 Ncm for group A, B, D and 20 Ncm for groups C and E).

A stainless steel cylinder was milled to obtain precise fit onto the abutments. Each cylinder had a round top. When tightening the test samples into the assembly, care was taken to align the angle toward the most pressure-resistant site of each respective sample, as assessed in previous examinations using finite element analyses.

For the critical bending test, a Zwick/Roell 1475 machine (Zwick/Roell, Ulm-Einsingen, Germany) was used (Figure 2). Pressure was applied with 100 kN at a speed of 5 mm/min. The preforce value was set to 3 N. During the test, the force was centered to the top of the abutment since the cylinder applying the pressure was fixed on a thrust bearing.

A software program (testXpert, Zwick/Roell) provided a continuous output of the applied loads and distances traveled by the piston. These were recorded in real time numerically and graphically. Parameters included F_{max} (maximum force in N), F_{max} elast (defined as force in N measured at 0.2% elastic strain offset), slope (representing stiffness of the entire system in N/mm between 100 N and 300 N within the entire system), and epsilon (representing displacement in mm). The software program stopped the progress of the force when permanent deformation and/or fracture occurred.

Statistical Analyses

Groups A, D, and E represented original implantabutment interfaces, whereas groups B and C represented non-original interfaces. For each group, the rotational misfit, failure mode, load displacement curves, and output of the ISO 14801 test were listed and/or graphically depicted. The analyses of variance started with the Kruskal–Wallis test and were followed



Figure 2 Assembly for the critical bending test in a ZWICK/ ROELL 1475 machine. Pressure was applied with 100 kN at a speed of 5 mm/min. Preforce at 3 N. Continuous output was provided by the software (Xpert, Zwick/Roell).

TABLE 1 Rotational Misfit: Mean, Standard Deviation (SD), Minimum, Maximum					
Group	Ν	Mean	Std. Dev.	Min.	Max.
Group A					
Implant Straumann	11	1.21*	0.236	0.83	1.67
Abutment Straumann					
Group B					
Implant Straumann	12	n.a.	n.a.	n.a.	n.a.
Abutment Nobel					
Group C					
Implant Straumann	12	2.01*	0.446	0.83	2.33
Abutment Astra					
Group D					
Implant Nobel	12	3.50*	0.285	3.00	4.00
Abutment Nobel					
Group E					
Implant Astra	11	2.50*	0.208	2.33	3.00
Abutment Astra					

*All pairwise comparisons (A–C, A–D, A–E, C–D, C–E, D–E) were statistically significantly different using Kruskal–Wallis test, Mann–Whitney *U*-test and Bonferroni–Holm adjustments (*p* < .05).

by pairwise comparison using Mann–Whitney U-test with Bonferroni–Holm adjustment (SAS® PROC NPAR1WAY).

RESULTS

Rotational Misfit

In Table 1, the rotational precision levels between abutment/implant interfaces were listed for each group. One specimen from group A was chosen as a pretest sample to run the entire series of tests. In this group, therefore, the remaining 11 samples were included for analyses. One sample from group E could not be prepared for the critical bending test as the fit of the stainless steel cylinder on to the CAD/CAM titanium abutment could not be obtained. Therefore, this group also contained 11 samples for analysis.

In group B, no measurements were possible since the non-original abutments were oversized and manual adjustments were necessary to connect the abutments with the implants. Three out of 12 abutments could not be removed after connection.

The rotational tolerance level between original components ranged from 3.0° to 4.0° in group D, from 2.33° to 3.0° in group E (Astra), and from 0.83° to 1.67° in group A. For group C, the rotational play ranged from 0.83° to 2.33°.

All combinations of comparisons indicated statistically significantly different values for rotational misfit (p = .05). The interface in group A was the most precise.

When the interfaces of the original abutments of group A were visually compared to the non-original interfaces of groups B and C, differences in design were obvious. While the CrossFit connection comprised two grooves and two surfaces, group B abutments demonstrated four grooves and four surfaces and group C abutments demonstrated only four surfaces without any grooves (Figure 3).

Load Displacement Curves

Figure 4 depicts graphically the progress of the force buildup and release for each test sample separately. While the original implant-abutment interface in group A showed a smooth displacement curve, in all the other groups, an uneven force buildup and release was noted. This effect is known as a stick/slip effect.

The numerical data output of the critical bending tests included the parameters:

 F_{max} = Maximal force needed up to fracture (N) F_{max} elast = Force measured at 0.2%

elastic strain offset (N)



Figure 3 Abutment interfaces of an original abutment of group A compared to the non-original interfaces of abutments originating from group B and C. Group A: CARES[®] abutment. Group B: Nobel Biocare Procera[®] abutment. Group C: Astra Tech Atlantis[®] abutment.

Slope (data not shown) = stiffness between 100 and 300 N(N/mm)

Epsilon (data not shown) = displacement in mm

Unexpectedly, the mechanical characteristics of the two non-original implant-abutment connections (groups B and C) were clearly different from the original connection (groups A, D, and E). F_{max} and F_{max} elast were statistically significantly increased when original implants (Straumann) were combined with non-original abutments (Nobel Biocare and Astra Tech) (Figure 5, A and B):

Group A: F_{max} 553 N ± 30 N, F_{max} elast 487 N ± 41 N Group B: F_{max} 700 N ± 32 N, F_{max} elast 538 N ± 40 N Group C: F_{max} 690 N ± 24 N, F_{max} elast 587 N ± 43 N

The original connections demonstrated similar resistance to the bending force (Figure 5, A and B):

Group A: F_{max} 553 N ± 30 N, F_{max} elast 487 N ± 41 N Group D: F_{max} 555 N ± 25 N, F_{max} elast 453 N ± 44 N Group C: F_{max} 508 N ± 43 N, F_{max} elast 439 N ± 49 N

In group A, the most consistent measurements were obtained, indicated by the smallest box plots.

Failure Modes

In general, the failure modes within one group were very similar (Figure 6).

- Group A. The uppermost part of the implant shank was minimally bent. At the level of the narrow CrossFit connection, the implants were deformed and widened. The abutments were severely bent at the level of the H-rotation "stop." The abutment screws broke at the junction between the core and the shank and the screw core.
- Group B. The head of the implants as well as the abutments were minimally distorted. The abutment

screws broke at the junction between the shank and the screw core.

- Group C. The abutments and the implants were minimally deformed. The abutments broke at the junction between the shaft and the screw core.
- Group D. In this group, the failure mode was clearly different from all other groups. The fractures occurred at the tension side about 2 mm below the platform. The broken heads of the implants and the abutments were intact with the exception that the abutment screws broke at the junction between the shaft and the screw core.
- Group E. The abutments were only slightly distorted. The neck portions of the implants were minimally widened. The abutment screws broke at the border between the shaft and the screw core.

DISCUSSION

For this experiment, abutment connections with diameter-reduced small implants were chosen in order to test a biomechanically more challenging condition compared to abutment connections with standard diameter implants.

Some literature evidence suggests that the use of diameter-reduced implants may result in higher rates of implant fractures.^{6,7} In order to reduce the risk of such fractures, new alloys such as titanium–zirconium (TiZr) were developed which demonstrated improved biome-chanical characteristics without changing the biological properties for tissue integration. Promising preliminary results have been reported for the safe use of diameter-reduced implants with such a TiZr alloy in cases treated with mandibular overdentures or with short-span fixed dental prostheses with a diameter-reduced implant splinted to an implant of standard diameter.^{13,14}

In clinical reality, dentists, technicians, and patients may opt for a non-original abutment for various reasons



Figure 4 Load displacement curves for each one of the implant abutment connections from group A, B, C, D, E. The piston moved with 5 mm/min, 3 N at start followed by 100 kN. Group A: Straumann BL NC 3.3 mm Roxolid (Institute Straumann, Basel, Switzerland) with titanium CARES® abutments (Institute Straumann, Basel, Switzerland). Group B: Straumann BL NC 3.3 mm Roxolid with Nobel Biocare Procera® abutments (Nobel Biocare, Kloten, Switzerland). Group C: Straumann BL NC 3.3 mm Roxolid with Astra Tech Atlantis® abutments (Astra Tech, Lausanne, Switzerland). Group D: Nobel Biocare Replace Straight 3.4 NP (Nobel Biocare, Kloten, Switzerland) with Nobel Biocare Tech, Lausanne, Switzerland) with Astra Tech Atlantis® abutments. Group E: Astra Tech OsseoSpeed TX 3.5S (Astra Tech, Lausanne, Switzerland) with Astra Tech Atlantis® abutments.



Figure 5 *A*, Maximal force (F_{max}) needed for fracture. $*F_{max}$ was statistically significantly increased when comparing the non-original connections (group B, C) with the original connections (A, D, E). $*F_{max}$ was statistically significantly smaller in group E compared to the other original connections (A, D), Mann–Whitney *U*-tests and Bonferroni–Holm adjustments (p < .05). *B*, Force measured at 0.2% of the elastic limit (F_{max} elast). $*F_{max}$ elast was statistically significantly increased when comparing the non-original connections (group B, C) with the original connections (A, D, E) using Mann–Whitney *U*-tests and Bonferroni–Holm adjustments (p < .05).

(e.g., cost, access, convenience). In an *in vitro* study,¹⁵ it was shown that CAD/CAM-generated non-original abutments of one manufacturer were designed to fit on top of the external hexagon of other implants and to fit into the bore of those implants. If original abutment screws were mixed with non-original abutments, the abutment screw heads did not fit into the abutment heads.

In another *in vitro* test,¹⁶ the degree of misfit between original abutments and original implants was approximately 50% of that observed with non-original abutments produced for implants from two other manufacturers. It was concluded that the connection of Procera Zirkonia abutments with other implant systems resulted in a higher vertical misfit at the implantabutment interface compared to the original connection.

In the present experiment, the non-original abutments in group B were oversized. The abutments had to be forcibly manipulated to be inserted into the implants; subsequently, three could no longer be removed. Thus, clinical handling was altered considerably. The rotational misfit of the second non-original abutment in group C was higher compared to the original connection of Straumann/Straumann.

A closer look at the designs of the abutment base matching the CrossFit connection revealed that the combination of grooves and surfaces was completely different in groups B and C compared to A. This explains the tightness and the mechanical differences observed in the subsequent load displacement test. The differences in design are most likely related to patent issues which do not allow the exact imitation of such components. The load displacement graphs also revealed a unique format for the original CrossFit connection compared to all other connections used. In group A, a smooth curve was drawn for the self-guiding CrossFit connection which did not result in a stick/slip effect.

The calculated F_{max} and F_{max} elast values were statistically significantly higher in groups B and C. In these groups, the abutment material was grade V titanium, which has a higher mechanical stiffness whereas in group A, an abutment of grade IV alloy, was tested. The connection of the stiffer abutments with the stronger Roxolid alloy implants appeared to increase the load needed for permanent deformation. The same stiffer abutment connected to its original implant resulted in the fractures at the implant neck observed in group D. The original connections in groups A and E caused very similar outcomes related to the load displacement curves and the fracture modes.

In conclusion, non-original abutments differ in the design of the connecting surfaces, shape, dimensions, and material and have higher rotational misfit. All these differences may result in unexpected failure modes and may have an adverse effect on clinical handling as demonstrated by the poor results in group B. In addition, there are no clinical studies known evaluating the influence of non-original abutments on implants and their



Figure 6 Deformation and/or fractures of implants or abutments at the end of the critical bending test observed in specimens of groups A, B, C, D, E. A, Deformation in the top part of the Roxolid implant and deformation of the abutment in the connection part and fracture of the abutment screw where the threads start. *B* and *C*, Deformation in the top part of the Roxolid implant and deformation of the abutments in the connection part and fracture of the abutment screw at the level where the threads start. Distortion A > B > C. *D*, Fracture of the implant in the neck part in the tension zone. The abutment was minimally bent and fractured between the guiding part and the screw part. *E*, Deformation in the top part of the implant and deformation of the abutment in the connection part and fracture of the abutment screw.

use may result in a potentially increased risk. Clinical studies testing the failure and complication rates of reconstructions on original and non-original connections should, therefore, be performed; however, on the basis of results from the current study, it should be recommended to use abutments from the original implant manufacturer when restoring implants.

REFERENCES

- Salvi GE, Bragger U. Mechanical and technical risks in implant therapy. Int J Oral Maxillofac Implants 2009; 24 (Suppl):69–85.
- Theoharidou A, Petridis HP, Tzannas K, Garefis P. Abutment screw loosening in single-implant restorations: a systematic review. Int J Oral Maxillofac Implants 2008; 23:681–690.
- Steinemann SG. Titanium the material of choice? Periodontol 2000 1998; 17:7–21.
- 4. Gottlow J, Dard M, Kjellson F, Obrecht M, Sennerby L. Evaluation of a new titanium-zirconium dental implant: a biomechanical and histological comparative study in the mini pig. Clin Implant Dent Relat Res 2010 [Epub ahead of print].
- Thoma DS, Jones AA, Dard M, Grize L, Obrecht M, Cochran DL. Tissue integration of a new titaniumzirconium dental implant: a comparative histologic and radiographic study in the canine. J Periodontol 2011; 82:1453–1461.
- Zinsli B, Sagesser T, Mericske E, Mericske-Stern R. Clinical evaluation of small-diameter ITI implants: a prospective study. Int J Oral Maxillofac Implants 2004; 19:92–99.
- Allum SR, Tomlinson RA, Joshi R. The impact of loads on standard diameter, small diameter and mini implants: a comparative laboratory study. Clin Oral Implants Res 2008; 19:553–559.

- Dixon DL, Breeding LC, Sadler JP, McKay ML. Comparison of screw loosening, rotation, and deflection among three implant designs. J Prosthet Dent 1995; 74:270–278.
- 9. Gratton DG, Aquilino SA, Stanford CM. Micromotion and dynamic fatigue properties of the dental implant-abutment interface. J Prosthet Dent 2001; 85:47–52.
- Khraisat A, Stegaroiu R, Nomura S, Miyakawa O. Fatigue resistance of two implant/abutment joint designs. J Prosthet Dent 2002; 88:604–610.
- Lee FK, Tan KB, Nicholls JI. Critical bending moment of four implant-abutment interface designs. Int J Oral Maxillofac Implants 2010; 25:744–751.
- Meng JC, Everts JE, Qian F, Gratton DG. Influence of connection geometry on dynamic micromotion at the implant-abutment interface. Int J Prosthodont 2007; 20:623–625.
- Al-Nawas B, Bragger U, Meijer HJ, et al. A double-blind randomized controlled trial (RCT) of Titanium-13Zirconium versus titanium grade IV small-diameter bone level implants in edentulous mandibles – results from a 1-year observation period. Clin Implant Dent Relat Res 2011 [Epub ahead of print].
- Barter S, Stone P, Bragger U. A pilot study to evaluate the success and survival rate of titanium-zirconium implants in partially edentulous patients: results after 24 months of follow-up. Clin Oral Implants Res 2011 [Epub ahead of print].
- Lang LA, Sierraalta M, Hoffensperger M, Wang RF. Evaluation of the precision of fit between the Procera custom abutment and various implant systems. Int J Oral Maxillofac Implants 2003; 18:652–658.
- 16. Alves da Cunha TD, Correia de Araujo RP, Barbosa da Rocha PV, Pazos Amoedo RM. Comparison of fit accuracy between procera custom abutments and three implant systems. Clin Implant Dent Relat Res 2010 [Epub ahead of print].

Copyright of Clinical Implant Dentistry & Related Research is the property of Wiley-Blackwell and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.