JMEPEG (2011) 20:947–951
DOI: 10.1007/s11665-010-9699-9

1059-9495/$19.00

Effect of Vertical Misfit on Screw Joint Stability of Implant-Supported Crowns

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(Submitted July 27, 2009; in revised form May 4, 2010)

The passive fit between prosthesis and implant is a relevant factor for screw joint stability and treatment success. The aim of this study was to evaluate the influence of vertical misfit in abutment-implant interface on preload maintenance of retention screw of implant-supported crowns. The crowns were fabricated with different abutments and veneering materials and divided into 5 groups (n = 12): Gold UCLA abutments cast in gold alloy veneered with ceramic (Group I) and resin (Group II), UCLA abutments cast in titanium veneered with ceramic (Group III) and resin (Group IV), and zirconia abutments with ceramic veneering (Group V). The crowns were attached to implants by gold retention screws with 35-N cm insertion torque. Specimens were submitted to mechanical cycling up to 10^6 cycles. Measurements of detorque and vertical misfit in abutment-implant interface were performed before and after mechanical cycling. ANOVA revealed statistically significant difference ($P < 0.05$) among groups for vertical misfit measured before and after mechanical cycling. The abutments cast in titanium exhibited the highest misfit values. Pearson correlation test did not demonstrate significant correlation ($P > 0.05$) between vertical misfit and detorque value. It was concluded that vertical misfit did not influence torque maintenance and the abutments cast in titanium exhibited the highest misfit values.

Keywords casting, material selection, optical microscopy, titanium

1. Introduction

The passive fit between prosthesis and implant is an important factor for treatment success to minimize the biological and mechanical failures as retention screw loosening (Ref 1-6).

The retention screw of implant-supported prostheses acts as a spring, which is stretched and maintained by the friction between the threads (Ref 7). A tension named preload is generated as the insertion torque is applied, which is a direct determinant of clamping force and essential for screw joint integrity (Ref 8). However, part of the preload is loss due to embedment relaxation of retention screw that depends on roughness between the mating surfaces (Ref 9).

Although Branemark et al. (Ref 1) have suggested a maximum misfit of 10 µm between the components, dimensional alterations resulting from fabrication may not be predicted. Such alterations may affect the marginal fit between components and the treatment success (Ref 4, 10).

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The long-term success of cylinders and casting with gold for implant-supported prostheses results from good biological and physical properties and adequate fit, but with a high cost (Ref 11). Therefore, the titanium became an option due to biocompatibility, resistance to corrosion and mechanical resistance to functional forces (Ref 10, 12, 13). However, the casting with titanium may exhibit porosities that influence fit (Ref 14) besides the specific technology for casting and bonding to ceramic (Ref 15).

Besides the metallic abutments, some ceramic abutments composed by alumina- or zirconia-reinforced ceramics (Ref 16, 17) can be obtained through CAD/CAM system (*computer-aided design/computer-aided manufacturing*) to avoid inadequate interfaces between components (Ref 18).

The selection of the veneering material must be judicious since it is related to the stress distribution and screw joint stability (Ref 19-22).

Therefore, the aim of this study was to evaluate the effect of misfit in the abutment-implant interface on preload maintenance of retention screw of implant-supported crowns.

2. Experimental Procedure

Five groups (n = 12) were obtained with different abutments and veneering materials: Group I—Gold UCLA abutments (Biomet 3i Inc., Palm Beach Gardens, FL, USA) cast in gold alloy with ceramic veneering, Group II—Gold UCLA abutment (Biomet 3i Inc., Palm Beach Gardens, FL, USA) cast in gold alloy with resin veneering, Group III—castable UCLA abutment (Biomet 3i Inc., Palm Beach Gardens, FL, USA) cast in titanium with ceramic veneering, Group IV—castable UCLA abutment (Biomet 3i Inc., Palm Beach Gardens, FL, USA) cast in titanium with resin veneering, and Group V—zirconia abutment obtained by CAD/CAM system (Procera Scanner Mod 50, Nobel Biocare, Göteborg, Sweden) with ceramic veneering.

All frameworks presented a conical shape with 6.5 mm in height and 5.0 mm in the major diameter with a unilateral plane at 30° of inclination in the occlusal surface. The sleeve of the abutments of groups I, II, III, and IV were coated with autopolymerizing acrylic resin (Duralay; Reliance Dental MFG Company, Worth, IL, USA). The zirconia abutments of group V were obtained through the scanning of a metallic abutment of group II by CAD/CAM system (Procera Scanner Mod 50, Nobel Biocare, Göteborg, Sweden). The scanned data were transferred to the Procera software (Procera software 2.2, Nobel Biocare, Göteborg, Sweden).

The patterns of groups I and II were invested with a phosphate investment (Gilvest HS, Servo Dental do Brasil, São Paulo, SP, Brazil) that was vacuum mixed (Polidental Ind. e Com. Ltd, Cotia, SP, Brazil) and poured under vibration (Knebel Produtos Dentários Ltda, Porto Alegre, RS, Brazil).

These patterns were cast in ceramic gold alloy (Gold Ceramic, CNG Soluções Protéticas, São Paulo, SP, Brazil) followed by finishing with aluminum oxide burs (Pedra Ninja, Talladium do Brasil, Curitiba, PR, Brasil) and sandblasting with 50 µm—aluminum oxide (Elfusa Geral de Eletrofusão Ltd, São João da Boa Vista, SP, Brazil).

The patterns of groups III and IV were invested with a specific investment for casting with titanium (Rematitan Ultra, Dentaurum, Ispringen, Alemanha). This investment was vacuum mixed (Polidental Ind. e Com. Ltda, Cotia, SP, Brasil) and poured under vibration (Knebel Produtos Dentários Ltda, Porto Alegre, RS, Brazil).

Thus, the patterns were positioned in a specific equipment (Rematitan autocast, Dentaurum, Ispringen, Germany) for casting with pure titanium grade 2 (Realum Ind. e Com. de Metais Puros e Ligas Ltda, São Paulo, SP, Brazil). After casting, the abutments were finished with aluminum oxide burs (Pedra Ninja, Talladium do Brasil, Curitiba, PR, Brazil) followed by sandblasting with 80 µm—aluminum oxide (Elfusa Geral de Eletrofusão Ltda, São João da Boa Vista, SP, Brazil).

The abutments of group I were veneered with a medium fusion ceramic (Compact Ceramic System/Carmen, Dentaurum, Ispringen, Germany) while the abutments of groups III and IV were veneered with a low fusion ceramic (Triceram-Titanium Ceramics, Dentaurum, Ispringen, Germany). The abutments of groups II and IV were veneered with light-curing resin (VitaVM LC, VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany). After veneering, the crowns present a conical shape with 8 mm in height and 8 mm in the major diameter with a plane with 30° of inclination in the occlusal surface (Ref 23).

For vertical misfit measurement, the crowns were attached to an external hexagon implant (3.75 mm in diameter, 15.0 mm in length, 4.1 mm platform) (OSSEOTITE Implant, Biomet 3i Inc., Palm Beach Gardens, FL, USA) with a gold retention screw (Gold-Tite square uniscrew, Biomet 3i Inc., Palm Beach Gardens, FL, USA) with a 5 N cm torque. The implant was embedded in a block of autopolymerizing acrylic resin (Jet; Artigos Odontológicos Clássico Ltd., São Paulo, SP, Brazil) to standardize the measurement of the vertical misfit. Images of abutment/implant interface were obtained by a digital camera (PowerShot A640, CANON, Japan) attached to the stereomicroscope (Stemi SV-11, Zeiss, Germany) under 66× magnification. The images were transferred to a software (Software AxioVision, Zeiss, Germany) for two measurements of the gap between abutment and implant (Fig. 1) in each side of the assembly (buccal, mesial, lingual, and distal), totalizing eight measurements in each crown. The vertical misfit measurement was performed before and after mechanical cycling.

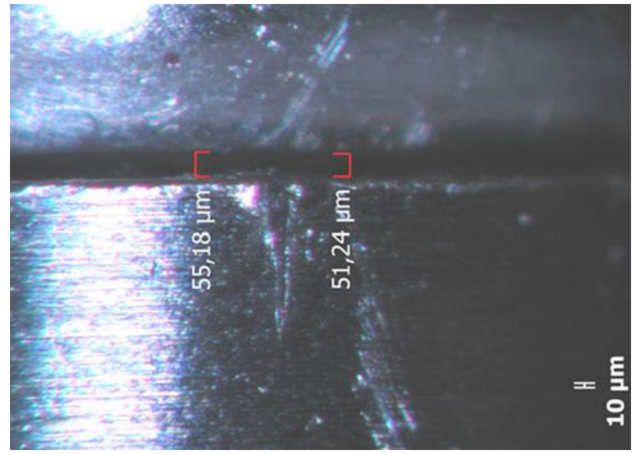

Fig. 1 Vertical misfit measurement at abutment/implant interface of a specimen of group III

Sixty external hexagon implants (3.75 mm in diameter, 15.0 mm in length, 4.1 mm platform) (OSSEOTITE Implant, Biomet 3i Inc., Palm Beach Gardens, FL, USA) were embedded in autopolymerizing acrylic resin (Jet; Artigos Odontológicos Clássico Ltd., São Paulo, SP, Brazil) perpendicular to the horizontal plane using a metallic matrix.

Before mechanical cycling, the crowns were attached to the implants with a gold retention screw (Gold-Tite square uniscrew, Biomet 3i Inc., Palm Beach Gardens, FL, USA) with 35 N cm insertion torque using an analogic torque gauge (BTG36CN-S, Tohnichi MFG. CO. Ltd, Tokio, Japan) and submitted to an initial detorque measurement (Fig. 2).

The specimens were positioned in an electromechanical machine for mechanical cycling (MSFM-ELQUIP, Equipments for Dental Research, São Carlos, SP, Brazil) under vertical dynamic loading with 50 N on the occlusal plane of each crown at 2 Hz. Detorque measurements were carried out after each period of 1×10^5 cycles followed by screw retightening with 35 N cm torque until complete 1×10^6 cycles.

Data were submitted to one-way analysis of variance (ANOVA) and Fisher's exact test ($P < 0.05$) considering the initial and final vertical misfit means among the groups. The initial and final values of detorque and vertical misfit of each group were compared by Student's t test ($P < 0.05$). In addition, Pearson's linear correlation test ($P < 0.05$) was performed to evaluate the correlation between vertical misfit and detorque.

3. Results

ANOVA revealed statistically significant difference ($P < 0.05$) among the groups regarding the initial ($P < 0.0001$) and final ($P < 0.0001$) vertical misfit means.

Fig. 2 Analogic torque gauge and specimen positioned in the device for torque insertion and detorque measurement

The groups III and IV exhibited the highest initial vertical misfit values with statistically significant difference ($P < 0.05$) in comparison to the other groups (Table 1). After mechanical cycling, the groups III and IV maintained the highest vertical misfit values. However, there was no statistically significant difference ($P > 0.05$) only between group I and groups II and IV (Table 2).

T-student test revealed significant difference ($P < 0.05$) between the initial and final vertical misfit means of all groups, except for group II ($P > 0.05$) (Table 3).

Considering the initial and final detorque means, there was statistically significant difference ($P < 0.05$) only for group IV (Table 4).

The Pearson's linear correlation test did not demonstrate significant correlation ($P > 0.05$) between vertical misfit and detorque (Table 5 and 6).

4. Discussion

According to the results, the hypothesis was rejected since the Pearson's correlation test did not establish significant correlation ($P > 0.05$) between vertical misfit and detorque.

The results demonstrated different vertical misfit levels among the groups with higher values for groups with abutments cast in titanium (Groups III and IV).

Sartori et al. (Ref 12) also demonstrated greater misfit in abutments cast in titanium than in gold alloy. According to the

Table 1 Fischer's exact test for mean (SD) of initial vertical misfit (μm) of groups I, II, III, IV and V

Groups	Mean (SD)*
I	24.98 (4.55)[a]
II	16.49 (4.74)[a]
III	67.69 (35.95)[b]
IV	77.56 (71.67)[b]
V	4.86 (1.15)[a]

* Means followed by different letters differ statistically ($P < 0.05$)

Table 2 Fischer's exact test for mean (SD) of final vertical misfit (μm) of groups I, II, III, IV and V

Groups	Mean (SD)*
I	18.78 (5.21)[a,c]
II	14.43 (9.05)[a]
III	38.38 (10.33)[b]
IV	26.77 (19.51)[c]
V	2.33 (1.37)[d]

* Means followed by different letters differ statistically ($P < 0.05$)

Table 3 Student's *t* test for means (SD) of initial and final vertical misfit (μm) of groups I, II, III, IV, and V

Groups	Initial vertical misfit mean (SD)	Final vertical misfit mean (SD)	Mean of differences (SD)	*T*	*P*
I	24.98 (4.55)	18.78 (5.21)	6.20 (5.64)	3.8095	0.0014
II	16.49 (4.74)	14.43 (9.05)	2.06 (7.94)	0.9000	0.1937
III	67.69 (35.95)	38.38 (10.33)	29.31 (29.34)	3.4609	0.0027
IV	77.56 (71.67)	26.77 (19.51)	50.79 (57.73)	3.0476	0.0055
V	4.86 (1.15)	2.33 (1.37)	2.53 (1.34)	6.5696	<0.0001

Table 4 Student's *t* test for means (SD) of initial and final detorque (N cm) of groups I, II, III, IV, and V

Groups	Initial detorque mean (SD)	Final detorque mean (SD)	Mean of differences (SD)	*T*	*P*
I	23.9 (0.91)	23.2 (2.44)	0.7 (2.18)	1.1786	0.1317
II	24.1 (1.34)	23.8 (1.56)	0.3 (1.00)	1.3562	0.1011
III	21.4 (1.78)	22.1 (1.86)	−0.7 (1.75)	−1.4854	0.0827
IV	23.2 (1.33)	23.6 (1.30)	−0.4 (0.67)	−2.2902	0.0213
V	21.9 (2.68)	21.7 (2.02)	0.2 (2.76)	0.2548	0.4018

Table 5 Pearson's linear correlation test between the initial detorque (N cm) and vertical misfit (μm) means (SD) of groups I, II, III, IV, and V

Groups	Detorque (SD)	Vertical misfit (SD)	*r*	*P*
I	23.9 (0.91)	24.98 (4.55)	−0.2203	0.7217
II	24.1 (1.34)	16.49 (4.74)		
III	21.4 (1.78)	67.69 (35.95)		
IV	23.2 (1.33)	77.56 (71.67)		
V	21.9 (2.68)	4.86 (1.15)		

Table 6 Pearson's linear correlation test between the final detorque (N cm) and vertical misfit (μm) means (SD) of groups I, II, III, IV, and V

Groups	Detorque (SD)	Vertical misfit (SD)	*r*	*P*
I	23.2 (2.44)	18.78 (5.21)	0.1169	0.8515
II	23.8 (1.56)	14.43 (9.05)		
III	22.1 (1.86)	38.38 (10.33)		
IV	23.6 (1.30)	26.77 (19.51)		
V	21.7 (2.02)	2.33 (1.37)		

authors, the misfit between implant and abutments cast in titanium may result from high melting point of the metal, low capacity of details reproduction and porosity (Ref 14). Furthermore, the high melting point of titanium demands the use of castable abutments, which increases the imperfections (Ref 4) in comparison to the use of prefabricated abutments as the Gold UCLA abutments (Ref 11) in groups I and II.

Kano et al. (Ref 9) also reported lower torque maintenance in castable abutments than in prefabricated abutments, concluding that casting may influence preload loss. According to the authors, the presence of irregularities between the mating surfaces generates greater embedment relaxation due to preload loss after wear of roughness, which may result in screw loosening.

Iglesia-Puig (Ref 10) presented the laser welding technique to connect parts constituted of the same alloy and avoid the limitation previously described. For this technique, the original titanium abutment can be used to preserve the fit between the components since the abutment is not placed in a furnace and, therefore, there is no thermal alteration in the metal.

In addition, Fonseca et al. (Ref 24) stated that the porcelain firing is an additional factor for marginal misfit in titanium abutments.

It is important to highlight that the groups III and IV exhibited high standard deviation values in comparison to the other groups, which demonstrates lack of uniformity on fit. These values may result from inherent characteristics of fabrication method including sprue's positioning for casting (Ref 4) and difficult finishing and polishing due to great hardness (Ref 15).

The reduction of vertical misfit after mechanical cycling was observed in all the groups, except for group II (Table 3). This finding may result from wear of irregularities and better fitting between the components as demonstrated by Hecker and Eckert (Ref 3) who reported reduced gap between implants and gold cylinders after mechanical cycling. Considering that the group II presented the lowest value of vertical misfit reduction (2.06 μm), there was no significant difference between the initial and final vertical misfit means (Table 3).

Although a few authors (Ref 2-6) have demonstrated the effect of misfit on screw joint stability, screw loosening is a multifactorial phenomenon including the stress distribution observed with the different materials (Ref 19-22) used for crown fabrication in this study.

Previous studies (Ref 1, 25) stated that acrylic resin absorbs part of the loading, which preserves the system against overloading and microfracture in the bone-implant interface while the rigid materials, as ceramic and metal, transfer the stress directly to the alveolar bone.

On the other hand, Cibirka et al. (Ref 26) demonstrated no significant difference for the coefficient of force absorption among composite resin, gold and porcelain. Soumeire and Dejou (Ref 27) also confirmed that a microparticle composite resin and a low fusion porcelain do not present advantages regarding stress absorption in comparison to conventional porcelain and gold crown.

Similarly, Wang et al. (Ref 28) demonstrated no significant difference for the stress generated in the peri-implant bone tissue between single restorations fabricated with resin, gold and porcelain. However, according to Ciftiçi and Canay (Ref 20) and Stegaroiu et al. (Ref 19), the reduced elasticity modulus of resin allows greater displacement and higher stress in the framework than porcelain.

Considering all these factors, no significant correlation ($P > 0.05$) between vertical misfit and joint stability was established (Table 5 and 6) since there was no significant difference ($P > 0.05$) between initial and final vertical misfit values even with a reduction of vertical misfit after mechanical cycling (Table 3), except for group IV (Table 4) that exhibited the highest vertical misfit reduction.

However, it should be considered that the detorque value was also influenced by screw retightening between the periods of mechanical cycling, which may have affected the effect of vertical misfit on joint stability after loading.

The accuracy of CAD/CAM system (Ref 18) for fabrication of zirconia abutments of group V provided a vertical misfit value inferior to the limit established by Branemark et al. (Ref 1) as biologically acceptable (10 μm) for treatment success. However, group V exhibited lower torque maintenance than the other groups (Table 4). This fact may be explained by a greater rotational misfit presented by the components fabricated with this system in comparison to the prefabricated metallic abutments as demonstrated by Garine et al. (Ref 6).

In addition, the effect of veneering material on stress distribution should be further considered for screw joint stability (Ref 19). The bond between veneering material and zirconia abutment presented limitations resulting in ceramic fracture in some specimens, which suggests additional studies to improve the characteristics of these materials.

According to the results, although there was no correlation between misfit and screw loosening, the professional should preserve the fit between components during fabrication since an acceptable misfit level with no mechanical and biological failures was not established (Ref 3).

5. Conclusion

According to the results and within the limitation of this in vitro study, it was concluded that

- The crowns obtained with UCLA abutments cast in titanium exhibited the highest vertical misfit values.
- There was significant reduction of vertical misfit after mechanical cycling, except for group II
- No significant correlation was found between vertical misfit and torque maintenance.

Acknowledgment

This study was supported by Foundation of Support to Research from State of São Paulo (FAPESP—07/53140-3 and 07/04181-9)/ Brazil.

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