In Vivo Stress Behavior in Cemented and Screw-Retained Five-Unit Implant FPDs

Matthias Karl, DMD;[1] Thomas D. Taylor, DDS, MSD;[2] Manfred G. Wichmann, DMD;[1] and Siegfried M. Heckmann, DMD[1]

Purpose: When fixing implant-supported fixed partial dentures (FPDs), it is important to achieve passive fit. The objective of the in vivo study presented was to quantify the strain development during the fixation of screw- and cement-retained FPDs.

Materials and Methods: After informed patient consent had been obtained (Ethics commission Approval No. 2315; FAU Erlangen-Nuremberg, Germany), four groups of five-unit FPDs (five samples per group) were fabricated and investigated in vivo. Group 1: Cementable, repositioning technique impression, burn out plastic coping; Group 2: Screwable, pickup technique impression, burn out plastic coping; Group 3: Screwable, pickup technique impression, cast to gold cylinder; Group 4: Screwable, pickup technique impression, bonded to gold cylinder. Two strain gauges (SG) were attached to the pontics of each bridge (SG-M and SG-D) to measure the strains that occurred during either the cementing or screw-in process. The final values were recorded for analysis.

Results: The mean strain values (μm/m) for each SG were: Group 1: SG-M 32 μm/m, SG-D: 89 μm/m; Group 2: SG-M 302 μm/m, SG-D: 197 μm/m; Group 3: SG-M 458 μm/m, SG-D: 268 μm/m; Group 4: SG-M 269 μm/m, SG-D: 52 μm/m.

Conclusions: Although the bridges were clinically acceptable, none of them revealed a truly passive fit with zero microstrain. In contrast to conventional screw-retained bridges, cement retention seems to result in lower strain levels. Bonding bridge pontics to prefabricated implant components seems to allow both the retrievability of a screw-retained bridge and produce moderate strain values.

J Prosthodont 2006;15:20-24. *Copyright © 2006 by The American College of Prosthodontists.*

INDEX WORDS: passive fit, strain development, cement retention, screw retention, in vivo, strain gauge

SEVERAL AUTHORS have addressed the issue of passive fit and the possible complications resulting from implant superstructures without passive fit.[1-8] Until now, however, passive fit itself has never been defined in biomechanical terms[9,10] besides signifying the absolute lack of strain development. As was shown in basic research studies on static implant loading evoked by the fixation of various implant restorations,[11,12] the need for a passively fitting superstructure[13] cannot be met with common techniques used in implant prosthodontics. The significance of passive fit for successful osseointegration is also still unknown.[1,4-17] Furthermore, according to Kan et al,[10] no methods of measuring passive fit as yet exist. Thus, the purpose of this study was to determine the stress situation of five-unit implant fixed partial dentures (FPDs) in vivo using the strain gauge (SG) technique. In doing so, not only could strain data for comparisons between different types of restorations be gained, but the SG-technique could also serve as an objective accuracy test for implant FPDs. Additionally, the obtained values will be used in an ongoing finite element analysis.

[1]Department of Prosthodontics, University of Erlangen-Nuremberg, Erlangen, Germany.

[2]Department of Prosthodontics, University of Connecticut, Farmington.

Accepted December 2, 2004.

Presented at the 19th Academy of Osseointegration Annual Meeting in San Francisco, CA, 2004.

Correspondence to: Siegfried M. Heckmann, DMD, School of Dental Medicine, University of Erlangen-Nuremberg, Glückstr. 11, 91054 Erlangen, Germany. E-mail: siegfried.heckmann@rzmail.uni-erlangen.de

Copyright © 2006 by The American College of Prosthodontists

1059-941X/06

doi: 10.1111/j.1532-849X.2006.00064.x

Materials and Methods

Preparations

A patient (male, 69 years) with three implants in the right portion of the maxilla (ITI solid screw implants, 4.1 mm diameter, 12 mm bone sink depth; Straumann

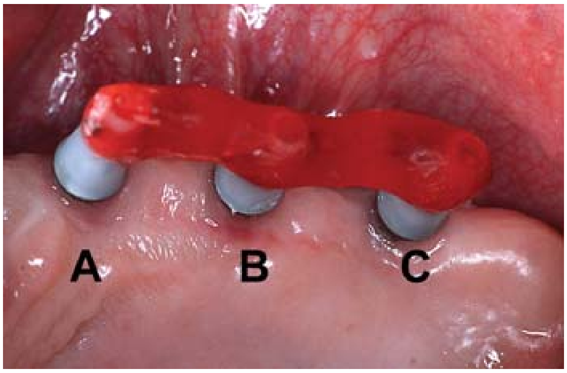

Figure 1. Basic impression of the implants in the right maxilla used to fabricate a master model from which repositioning and pickup technique impressions were taken for fabrication of FPDs.

AG, Waldenburg, Switzerland) and preattached solid abutments volunteered for the investigation presented (Erlangen University Ethics Commission; Approval No. 2315). As 20 five-unit restorations were to be fabricated according to clinical protocol including impression taking, it was decided that, for ethical reasons, the implant positions would be transferred to a master model. Plastic copings "crown" (Straumann AG) with lateral extensions were therefore placed onto the solid abutments and connected with a tiny amount of resin (Palavit G®, Heraeus Kulzer, Hanau, Germany; Fig 1).

Three original ITI solid screw implants assembled with 5.5 mm solid abutments were repositioned into the basic impression and fixed in an epoxy resin block (Araldit®, Ciba Geigy, Wehr, Germany). Subsequently, impressions were taken from the master model and stone casts were made for each bridge. Custom-made impression trays (Palatray XL®, Heraeus Kulzer) were fabricated, allowing impressions to be taken according to either the pickup technique or the repositioning technique using a polyether impression material (Impregum®, ESPE, Seefeld, Germany) for all impressions. Degudent U®, a high precious metal fused to ceramics alloy (DeguDent, Hanau, Germany) was used to cast all of the FPDs. Manufacturers' protocols were strictly observed in every step of superstructure fabrication. All samples were fabricated by the same master dental technician and were evaluated by common visual and tactile methods both on the stone casts, the master model, and in the oral cavity to ensure their clinically acceptable fit. Table 1 categorizes and describes the four FPD groups studied.

Protocol for Bonded FPDs

In addition to standard procedures of FPD fabrication, an innovative method[18] was introduced. In the bonded group (Group 4), premachined gold cylinders served as a basis. Separately cast bridge frames were conditioned using Silicoater MD® (Heraeus Kulzer) and bonded to the gold cylinders on the master model using Degufill® (DeguDent).

Table 1. Abbreviation for Different FPD Types

Group 1: cementable; repositioning technique impression; burn out plastic coping
Group 2: screwable; pick-up technique impression; burn out plastic coping
Group 3: screwable; pick-up technique impression; cast to gold cylinder
Group 4: screwable; pick-up technique impression; bonded to gold cylinder

Measurement Equipment and Protocol

Two SGs (SG; LY11-0.6/120, Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany) were placed on the occlusal surfaces of the bridge pontics (SG-Mesial and SG-Distal) and a measurement amplifier (DMC 9012A, Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany) was used in combination with BEAM® software (AMS Gesellschaft für angewandte Mess-und Systemtechnik GmbH, Flöha, Germany) to analyze the strains occurring. A special adhesive (PU-120; Hottinger Baldwin Messtechnik GmbH) was used to coat the SGs to avoid any disturbances that might occur due to saliva (Fig 2).

Measurement Protocol for Cement Groups

Temporary cement (ImProv®, Nobel Biocare, Cologne, Germany) was used for all cementing procedures. In order to reduce the cement strength an additional one third (by volume) of petroleum jelly[19] was added. With cement applied to the inner parts of the bridge abutments, the SGs were set to zero and the FPDs placed onto the solid abutments. The patient applied maximum biting force for 10 seconds and then reduced it to a degree he was able to hold for a further 3 minutes. The superstructures were then relieved and the cement allowed to set for another 2 minutes (Fig 3A and B). The measurement period lasted a total of 6 minutes.

Measurement Protocol for Screw Groups

The solid abutments were replaced by synOcta abutments with a torque of 35 Ncm applied using the implant manufacturer's ratchet. Both SGs were set to zero and the bridges placed onto the abutments. The occlusal screws were tightened onto the synOcta abutments with a torque of 20 Ncm using an electric torque controller[20] (Nobel Biocare). The fixation screws were secured onto the synOcta abutments in the following order: first step:

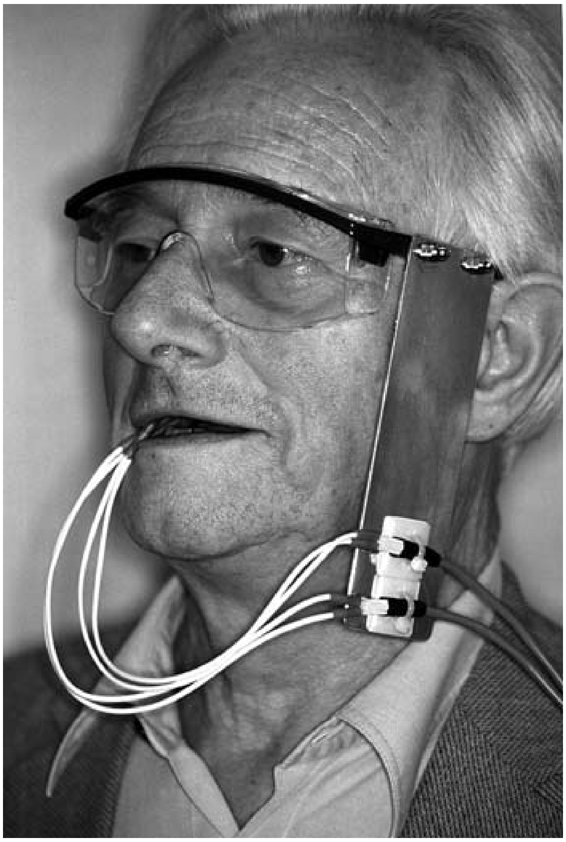

Figure 2. Volunteer with bridge placed on the implants, the goggles were utilized to hold the shielded wires in place. Patient consent was obtained for taking and publishing photographs.

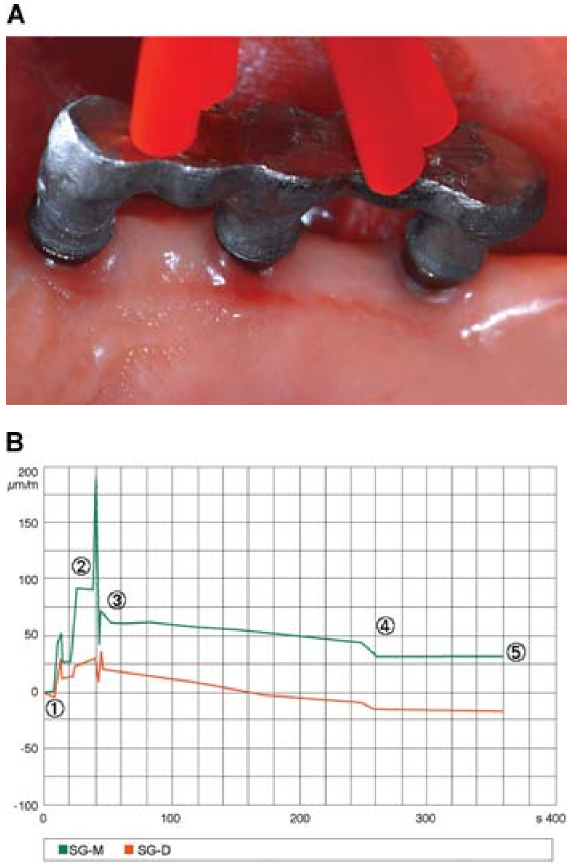

Figure 3. (*A*) Cementable FPD with strain gauges SG-M and SG-D placed on the abutments in the oral cavity for in vivo measurement. (*B*) Strain gauge signals of SG-M and SG-D during cementing procedure (*x*-axis: time in seconds; *y*-axis: strain in µm/m). (1) SG set to zero; (2) bridge placed on implants; maximum biting force applied; (3) force reduced and held for 3 minutes; (4) bridge relieved; (5) final strain values recorded for analysis.

occlusal screw at the mid-standing implant; second step: occlusal screw at the distal implant; third step: occlusal screw at the mesial implant. The strains occurring were measured after 6 minutes. A new set of occlusal screws was used for each bridge (Fig 4).

Mathematical Calculation

As a SG is only capable of detecting strains in a very limited sector, tensile or compressive forces are recorded more or less at random. Therefore, the absolute strain values were used for evaluation as they appear to allow comparisons between the strain magnitudes resulting from different modes of bridge fabrication and retention.

A statistical comparison between the FPD groups had already been performed on the basis of extensive in vitro testing on the described master model.[11,12] As the aim of this study was to gain basic biomechanical values for finite element analysis, it was decided not to perform statistical comparisons based on the in vivo values.

Results

The mean strain development and standard deviations for the four bridge groups calculated from the absolute values of the measurement results are depicted in Table 2.

Discussion

Passive fit has been described as an objective when fabricating implant-borne restorations.[1-4] In the study at hand, all types of FPDs investigated showed considerable levels of strain. Thus, it can be concluded that the FPDs investigated had a certain degree of misfit in spite of having

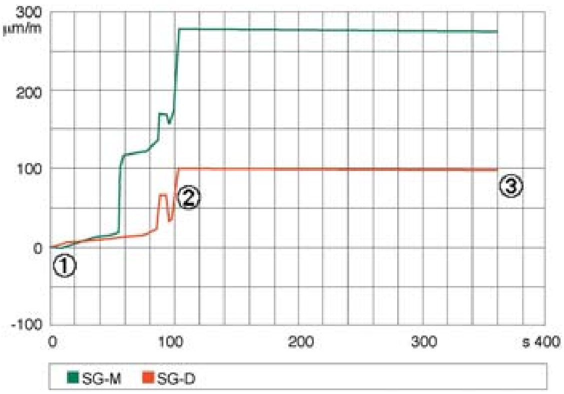

Figure 4. Illustration of strain gauge signal of SG-M and SG-D during screw fixation (*x*-axis: time in seconds; *y*-axis: strain in μm/m). (1) SG set to zero; (2) bridge placed on implants and SCS screws tightened; (3) final strains recorded for analysis.

been fabricated by a master dental technician and evaluated as clinically acceptable. This means that it seems to be difficult, if not impossible, to produce an implant-supported bridge that exhibits a true passive fit; in other words, with the SGs showing "zero microstrains."[11,12] In contrast to conventional screw-retained bridges, cement retention seems to produce lower strain levels. It can be assumed that the cement layer may have the capability of compensating shortcomings in bridge fabrication to a certain degree.[3] Only the bonded FPDs showed comparatively low levels of strain. One reason for this may be the fact that the prefabricated gold cylinders used are not exposed to possibly detrimental processes such as casting on, devesting, and polishing, as is the case in all other fabrication methods. Superstructure inaccuracies resulting from the casting process are removed when the bridge frame is tried in, thus verifying that it can be placed over the gold cylinders without any contact spots between superstructure and gold cylinders fixed on the implants.[18] The matching surfaces are then joined using a composite adhesive. As these two steps, i.e., fitting the FPD frame and the bonding process per se, are carried out directly on the implants, the inaccuracies caused by impression taking are eliminated as well. Thus, moderate strain levels and retrievability can be achieved.

Table 2. Absolute Mean Final Strain Valued in (μm/m) for the Four FPD Groups, with Standard Deviations

	SG-M		*SG-D*	
	Mean value	*(SD)*	*Mean value*	*(SD)*
Group 1:	32.54	(14.78)	89.28	(172.52)
Group 2:	302.38	(83.49)	197.00	(139.27)
Group 3:	458.54	(258.99)	268.12	(131.42)
Group 4:	269.84	(64.84)	52.96	(52.68)

Setup Critique

The magnitude of the in vivo strain levels may be exaggerated to a certain degree when compared with restorations fabricated in the normal protocol. In the study at hand, all FPDs were fabricated on the basis of impressions taken from the master model, which served as a "virtual" patient. Thus, the strain levels measured in vivo did not only result from inaccuracies in the fabrication process, but also from inevitable shortcomings in the transfer from the patient situation to the master model. For reasons of comparability, the screw-retained bridges bonded to gold cylinders were assembled on the master model and not in the oral cavity. Thus, the inaccuracies inherent in the basic impression can also be seen in this FPD group. It can be assumed that these superstructures would have shown lower strain development than the cementable ones did.

Another limitation of the presented study is the use of SGs as measuring devices, as their reliability can easily be influenced, e.g., by humidity. Although maximum effort was applied to avoid any disturbances, a certain influence through the experimental setup has to be considered. Nevertheless, the SGs have proven to show consistent data when compared to the in vitro measurements conducted prior to the in vivo study presented here.[12]

The mesial and distal pontic SGs did not show comparable values which might be due to the following aspects: the distances between the implants differed slightly, the implant axes were tilted and, additionally, the implants showed different Periotest values (A: 0; B: 1; C: 2).

Conclusions

There is evidence that not only cemented and screw-retained FPDs, but also bridges fabricated in a process involving the bonding of separately cast bridge frames onto prefabricated components show measurable strains. This allows the conclusion to be drawn that there are shortcomings in superstructure accuracy and no true passive fit can be achieved. Although static loading may not immediately lead to implant loss or superstructure failure, as good long-term results for both cemented and screw-retained prostheses indicate, it should be borne in mind that over the years a number of risk factors may supervene. It must be assumed that passively fitting restorations reduce the risk of both biological and mechanical failure. As superstructure bonding compensates at least the inaccuracies resulting from impression taking and laboratory procedures, it closely approximates the postulation of a passively fitting restoration. The study design presented here verifies that clinical fit evaluation methods[21] are not capable of detecting "hidden" inaccuracies in implant restorations. With the more sensitive SG technique, it would be possible to introduce an objective accuracy test for implant-supported restorations.

Acknowledgment

This project was supported by a grant from the ITI Foundation for the Promotion of Oral Implantology, Switzerland and DeguDent, Hanau, Germany.

References

1. Hebel KS, Gajjar RC: Cement-retained versus screw-retained implant restorations: achieving optimal occlusion and esthetics in implant dentistry. J Prosthet Dent 1997;77:28-35
2. Chee W, Felton DA, Johnson PF et al: Cemented versus screw-retained implant prostheses: which is better? Int J Oral Maxillofac Implants 1999;14:137-141
3. Misch CE: Screw-retained versus cement-retained implant-supported prostheses. Pract Periodontics Aesthet Dent 1995;7:15-18
4. Michalakis KX, Hirayama H, Garefis PD: Cement-retained versus screw-retained implant restorations: a critical review. Int J Oral Maxillofac Implants 2003;18:719-728
5. Kunavisarut C, Lang LA, Stoner BR et al: Finite element analysis on dental implant-supported prostheses without passive fit. J Prosthodont 2002;11:30-40
6. Assif D, Marshak B, Schmidt A: Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216-222
7. Sahin S, Cehreli MC: The significance of passive framework fit in implant prosthodontics: current status. Implant Dent 2001;10:85-92
8. Wee AG, Aquilino SA, Schneider RL: Strategies to achieve fit in implant prosthodontics: a review of the literature. Int J Prosthodont 1999;12:167-178
9. Hecker DM, Eckert SE: Cyclic loading of implant-supported prostheses: changes in component fit over time. J Prosthet Dent 2003;89:346-351
10. Kan JY, Rungcharassaeng K, Bohsali K et al: Clinical methods for evaluating implant framework fit. J Prosthet Dent 1999;81:7-13
11. Heckmann SM, Karl M, Wichmann MG et al: Cement fixation and screw retention: parameters of passive fit. An in vitro study of three-unit implant-supported fixed partial dentures. Clin Oral Implants Res 2004;15:466-473
12. Karl M, Winter W, Taylor TD, et al: In vitro study on passive fit in implant-supported 5-unit fixed partial dentures. Int J Oral Maxillofac Implants 2004;19:30-37
13. Brånemark PI, Hansson BO, Adell R et al: Osseointegrated implants in the treatment of the edentulous jaw. Scand J Plast Reconstr Surg 1977;16:1-132
14. Melsen B, Lang NP: Biological reactions of alveolar bone to orthodontic loading of oral implants. Clin Oral Implants Res 2001;12:144-152
15. Duyck J, Ronold HJ, Van Oosterwyck H et al: The influence of static and dynamic loading on marginal bone reactions around osseointegrated implants: an animal experimental study. Clin Oral Implants Res 2001;12:207-218
16. Carr AB, Gerard DA, Larsen PE: The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. J Prosthet Dent 1996;76:500-509
17. Jemt T, Lekholm U, Johansson CB: Bone response to implant-supported frameworks with differing degrees of misfit preload: in vivo study in rabbits. Clin Implant Dent Relat Res 2000;2:129-137
18. Watanabe F, Uno I, Hata Y et al: Analysis of stress distribution in a screw-retained implant prosthesis. Int J Oral Maxillofac Implants 2000;15:209-218
19. Michalakis KX, Pissiotis AL, Hirayama H: Cement failure loads of 4 provisional luting agents used for the cementation of implant-supported fixed partial dentures. Int J Oral Maxillofac Implants 2000;15:545-549
20. Haack JE, Sakaguchi RL, Sun T et al: Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10:529-536
21. Tan KB: The clinical significance of distortion in implant prosthodontics: is there such a thing as passive fit? Ann Acad Med Singapore 1995;24:138-157

Copyright of Journal of Prosthodontics is the property of Blackwell Publishing Limited 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.

Copyright of Journal of Prosthodontics is the property of Blackwell Publishing Limited 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.