Prospective observation of CAD/CAM titanium ceramic single crowns: A three-year follow up

Arne F. Boeckler, DMD, Dr Med Dent,[a] Heeje Lee, DDS,[b] Anke Stadler, DMD, Dr Med Dent,[c] and Jürgen M. Setz, DMD, Dr Med Dent Habil[d]

Martin-Luther-University Halle-Wittenberg, Center for Dentistry and Oral Medicine, Halle (Saale), Germany; Louisiana State University Health Sciences Center School of Dentistry, New Orleans, La

Statement of problem. Computer-aided design/computer-aided manufacturing (CAD/CAM) titanium ceramic restorations were developed with the potential for replacing expensive, high noble metal ceramic restorations. However, there is a lack of information about the clinical performance of CAD/CAM titanium ceramic single crowns.

Purpose. The purpose of this study was to evaluate CAD/CAM titanium ceramic single crowns after 3 years in function.

Material and methods. A total of 41 crowns were fabricated for 21 patients. The titanium copings were CAD/CAM milled (Everest CAD/CAM system) with an even thickness of 0.5 mm, and low-fusing veneering porcelain (Vita Titanium Porcelain) was added incrementally. The crowns were cemented using zinc phosphate cement after confirming that there were no mechanical and biological complications. The patients were recalled at 12, 24, and 36 months after cementation to examine the presence of any complications and measure periodontal parameters such as probing depth (PD), bleeding on probing (BOP), and plaque index (PI). The success and survival rates were estimated using the Kaplan-Meier analysis.

Results. The success rate of CAD/CAM titanium ceramic crowns with regard to mechanical complications was 82.3% (95% confidence interval: 71.2% to 95.1%). The cumulative survival rate of the crowns was 94.9% (95% confidence interval: 88.3% to 100%) after 3 years. No biological complications were observed. At the end of the follow up, PD was 2.93 mm, percentile of surface with BOP was 29.2, and PI was 0.31.

Conclusions. The clinical performances of the CAD/CAM titanium ceramic crowns for 3 years were acceptable, with no biologic complications and a high cumulative survival rate. (J Prosthet Dent 2009;102:290-297)

CLINICAL IMPLICATIONS
The CAD/CAM titanium ceramic crown may be an affordable substitute for a conventional high noble metal ceramic crown. In the future, technical improvements that allow milling of an anatomic coping may increase the success rate of these crowns.

---

[a]Assistant Professor, Center for Oral Medicine, Department of Prosthodontics, Martin-Luther-University Halle-Wittenberg.
[b]Assistant Professor, Department of Prosthodontics, Louisiana State University Health Sciences Center School of Dentistry.
[c]Resident, Center for Oral Medicine, Department of Prosthodontics, Martin-Luther-University Halle-Wittenberg.
[d]Professor and Chair, Center for Oral Medicine, Department of Prosthodontics, Martin-Luther-University Halle-Wittenberg.

Titanium as a coping material for metal ceramic restorations has received attention in dentistry, with the idea that it could be used as an affordable alternative for expensive precious metal alloys. Despite the long-term clinical success of restorations using precious metal alloys,[1-5] the increasing price of gold has become a significant driving force to seek alternatives. Besides its lower cost, other characteristics of titanium, such as its excellent biocompatibility, high corrosion resistance, low specific gravity, and appropriate mechanical properties, are appealing to clinicians.[6-8]

However, the high melting temperature of titanium has made the casting process difficult, and the high affinity of molten titanium to investment materials has created reactive alpha-case layers during the casting process.[9,10] It was found that the bond strength between titanium and porcelain was compromised due to the existence of the reactive layer.[11,12] While several methods, such as modifying air pressure and burn-out temperature or using different investment materials, were evaluated to improve the quality of the titanium casting,[13-17] a noncasting method was also developed to fabricate the metal copings of the titanium ceramic crowns.

An initial alternative method used machine duplication and spark erosion techniques.[18] The external form of the coping was made by copy milling from a titanium rod, and its internal surface was processed by spark erosion using a graphite electrode that was also formed by copy milling from the die. The resultant titanium coping required special veneering porcelain that was developed with a low coefficient of thermal expansion, because titanium's coefficient of thermal expansion is significantly lower than that of conventional noble metal alloys.[19,20] Also, the coping required veneering porcelain with a firing temperature below 880°C, because heating above this temperature transforms titanium from the hexagonal alpha phase to the body-centered cubic

beta phase, causing a critical dimensional change in the coping.[21] Moreover, firing the veneering porcelain at a higher temperature was found to create the oxide layer that resulted in reduced oxide adherence to the surface of the metal coping.[11]

The titanium ceramic crowns fabricated with the previously described methods (copy milling, spark erosion, and low-fusing porcelain) were applied in several clinical studies, and consistent results were reported.[22-27] During 2 to 6 years of follow up, few crowns needed to be replaced due to veneering porcelain fracture and caries. Of the various clinical factors evaluated, only surface texture and shade of the low-fusing veneering porcelain were found to deteriorate. Otherwise, the crowns demonstrated optimal results, and it was found that the titanium ceramic crowns were comparable to conventional metal ceramic crowns in terms of clinical performance.[23,27]

Later, computer-aided design/computer-aided manufacturing (CAD/CAM) technology was incorporated to make the titanium coping fabrication process simpler and faster.[28] In the CAD/CAM method, the die on the definitive cast was scanned, using either an optical or touch probe scanner, to send data to a computer. After digitizing the die, the coping was virtually designed on the computer using the acquired data and system-specific CAD software, and then the electronic file was transferred to a special milling unit to fabricate the coping. Contemporary CAD/CAM systems are able to fabricate not only the single crown coping, but also the metal framework for a fixed partial denture of up to 14 units, or customized implant abutments.[29,30] As for the accuracy of the products, even though CAD/CAM technology is relatively new and requires improvement, the speed with which it has been developed to yield results comparable to the conventional lost-wax technique is noteworthy.[31-35]

When CAD/CAM titanium ce-

ramic crowns were fabricated, there was a difference in the shape of the coping compared to that of conventional metal ceramic crowns. Since the porcelain is not resistant to tensile or shear stress, it was believed that the veneering porcelain should not be added in excessive amounts to the metal coping, so as to avoid increasing the tensile or shear stress.[36] For conventional metal ceramic crowns, full-contour waxing and cutting back the wax with an even thickness result in anatomic copings that provide adequate space for the veneering porcelain with proper support. However, the earlier version of CAD software was limited to designing the metal coping with an even thickness all around, on the given shape of the die. As a result, crowns were fabricated with excess veneering porcelain in certain areas. However, the authors identified no clinical studies that describe the general performance of the CAD/CAM titanium ceramic crowns with the specific coping design. Therefore, the purpose of the prospective clinical study was to evaluate the success, survival rate, and clinical parameters of CAD/CAM titanium ceramic single crowns after 3 years in function. The null hypotheses were: (1) the CAD/CAM titanium ceramic crowns would function intraorally with no mechanical complications for 3 years; and (2) the CAD/CAM titanium ceramic crowns would survive intraorally without requiring replacement for 3 years.

MATERIAL AND METHODS

This prospective clinical trial was designed according to the Consolidated Standards of Reporting Trials (CONSORT) recommendations for improving the quality of clinical trials.[37] The requirements of the Helsinki declaration were fulfilled and approved by the Ethical Committee of the Martin-Luther-University Halle-Wittenberg (#05032004).

Twenty-one patients (8 men, 13 women) between the ages of 26 and 67 (average age, 49.4)

participated in the study. Since the study design was developed as a prospective observation without a control group, no statistical method was applied to determine adequate sample size. Instead, the authors attempted to maximize the number of subjects within the limitations of the allowable study budget so as to collect nonbiased, generalizable results. When a patient visited the Department of Prosthodontics, Martin-Luther-University Halle-Wittenberg, Germany, with his/her restorative needs, the patient was introduced to CAD/CAM titanium ceramic restorations as a treatment option. The patients were informed about benefits/risks of the clinical trial on this new restorative system, and were asked if they were willing to participate. When the patient comprehended the research project and signed the consent form, the patient was registered as a study patient and followed for 3 years.

All patients needed at least 1 crown. To be included in the study, the prospective tooth for the single crown had to fulfill several clinical criteria; assessment was performed with medical/dental history taking and clinical and radiographic examinations. The tooth was required to be: (1) periodontally healthy; (2) vital, or with root canal treatment that was adequate (no clinical sign or symptom, no apical radiolucency); (3) correctly positioned in the dental arch; and (4) with a sufficient amount of coronal tooth structure and a ferrule at least 2 in mm height in dentin after preparation. Furthermore, normal occlusal function, a healthy temporomandibular joint, and a favorable interocclusal relationship were required. Patients with untreated temporomandibular disorders or untreated systemic or infectious diseases were excluded from the study. Pregnant women were also excluded from the study.

Forty-one CAD/CAM titanium ceramic single crowns (12 anterior, 29 posterior) were placed by faculty members of the Department of Prosthodontics who had 4 to 6 years of clinical experience. The teeth were prepared according to preparation guidelines for conventional metal ceramic crowns. A circumferential deep chamfer margin (1.2 mm in width) was created, and occlusal reduction of 1.5 to 2 mm was made. After the preparation, a complete arch impression was made using a combination of heavy- and light-body polyether (Impregum, Heavy Body and Permadyne, Light Body; 3M ESPE, Seefeld, Germany) with a custom impression tray (Diatray Top; Dental Kontor GmbH, Stockelsdorf, Germany). Provisional crowns were fabricated using bis-GMA material (Protemp Garant; 3M ESPE) and cemented using provisional cement (TempBond; KerrHawe SA, Bioggio, Switzerland).

The final crowns were fabricated using a CAD/CAM system (Everest CAD/CAM System; KaVo Dental GmbH, Biberach, Germany). The impression was poured in a type IV dental stone (Everest Rock; KaVo Dental GmbH). After separation from the impression, the definitive cast was trimmed and scanned using a special, coded-light charge-coupled device (CCD) camera (Everest Scan; KaVo Dental GmbH). The software (Everest Design Sherpa; KaVo Dental GmbH) automatically captured the preparation margin and the die surface, and then the dental laboratory technician designed the coping using the software. A 0.5-mm-thick coping, as commonly used for conventional metal ceramic restorations, was designed. The final data were transferred to the 5-axis milling unit (Everest Engine; KaVo Dental GmbH) so that the coping could be made by milling a grade-2 titanium blank (Everest T-Blank; KaVo Dental GmbH).

The fit of the titanium copings was evaluated intraorally prior to porcelain addition using a dental explorer (EXS3A6; Hu-Friedy Mfg Co, Chicago, Ill) and disclosing silicone material (Fit Checker; GC Corp, Tokyo, Japan). Once the fit was confirmed to be satisfactory, the coping was veneered with low-fusing porcelain (VITA Titanium Porcelain; VITA Zahnfabrik, Bad Säckingen, Germany). The crowns in the area up to and including the second premolar were fabricated with the buccal porcelain butt margin. As a result, 20 crowns were made with a buccal porcelain butt margin, whereas 21 were made with a metal margin. At the time of insertion, the proximal contacts and occlusion were adjusted as needed, and the crowns were cemented using zinc phosphate cement (Harvard; Richter & Hoffmann Harvard Dental GmbH, Berlin, Germany).

Immediately after cementation, probing depth (PD), bleeding on probing (BOP), and plaque index[38] (PI) of the restored teeth were measured. Probing depth was measured to the nearest level marked on a periodontal probe (Williams SE Probe; Hu-Friedy Mfg Co).[39] Bleeding on probing was observed, waiting for 30 seconds after removal of the periodontal probe from the gingival crevice.[40] Criteria for the PI was as follows; 0, no plaque; 1, no plaque visible, but plaque is visible on the point of the probe after it has been moved across the surface of the gingival crevice; 2, gingival area is covered with a thin to moderately thick layer of plaque; 3, heavy accumulation of soft matter.[38] Periapical radiographs (Fig. 1) and clinical photographs of the crowns were also made, and it was confirmed that all of the restorations were free of any technical complications such as cracks or other defects on the veneering porcelain.

At 12, 24, and 36 months after cementation, the patients were recalled and the restorations were examined for technical and biological complications by 2 calibrated faculty members. The calibration training was provided by a senior prosthodontist before the study began. The follow-up examinations consisted of clin-

1 Radiograph showing unsupported porcelain in marginal ridge areas.

ical, radiographic, and clinical photographic examinations. The clinical photographs were made from the buccal and occlusal views for each tooth using a standardized camera setting (aperture 22, shutter speed 1/80) (EOS 300D; Canon, Inc, Tokyo, Japan) and lens setting (1:1 ratio) (SP AF90mm F/2.8 Di 1:1; Tamron USA, Inc, Commack, NY). Radiographs were made to examine possible periapical radiolucencies. If apical radiolucency was suspected, additional radiographs from different angles were made.

As regards the evaluation of the mechanical complications of the veneering porcelain, a new, practical classification was introduced and used as follows: (1) Class I: minute crack that is visible by changing the direction of the light source; (2) Class II: clear fissure with discoloration; (3) Class III: chipping within the body of porcelain; and (4) Class IV: flaking of porcelain with metal coping exposure. Other mechanical complications of the crowns, if any, were observed and reported.

If porcelain fracture occurred, the situation was managed according to the severity of the incidence. Most of the fractures (n=5) were managed by procedures ranging from simple polishing to repairing using a self-etching bonding system (Clearfil SE Bond; Kuraray Co, Ltd, Osaka, Japan) and a silane coupling agent (Clearfil Porcelain Bond Activator; Kuraray Co, Ltd) in combination with a composite resin material (Tetric Ceram; Ivoclar Vivadent).

A possible deterioration in the shade of the veneering porcelain was assessed using a shade guide (VITA Toothguide 3D-MASTER; VITA Zahnfabrik). The change in the porcelain shade was confirmed by 2 investigators. Biological complications such as secondary caries, periapical radiolucency, and loss of tooth vitality were observed and reported if found. The periodontal parameters (PD, BOP, and PI) were measured to be compared with those of the baseline.

The crown was categorized as "success" if it was free from any mechanical and biological complications, while it was categorized as "survival" if it was functioning in place with complication(s), but not replaced. The success and survival rates were estimated using the Kaplan-Meier analysis with 95% confidence intervals.

RESULTS

During the 3-year follow up, veneering porcelain fracture occurred on 7 crowns that resulted in replacement of 2 crowns. The fractured crowns were found in different patients. Mechanical complications were found in 1 anterior crown and 6 posterior crowns, and 5 crowns had porcelain chipping off (Class III or IV) (Fig. 2). The 2 crowns that needed to be replaced were both posterior crowns, and the fracture of the porcelain caused loss of either occlusal or proximal contact. No biologic complications were found during the follow-up examinations. The PD mean constantly increased from 2.20 mm (baseline) to 2.93 mm (36 months), but the rate of increase diminished from 24 to 36 months (Table I). The PI mean and the percentage of surfaces


2 Clinical photograph showing veneering porcelain fracture.

TABLE I. Results of periodontal examinations

Parameter	Baseline (n=41)	12 Months (n=37)	24 Months (n=37)	36 Months (n=36)
Mean probing depth (mm)	2.20	2.22	2.74	2.93
Percentage of surface with bleeding on probing	17.1	25.7	29.1	29.2
Mean plaque index	0	0.35	0.35	0.31
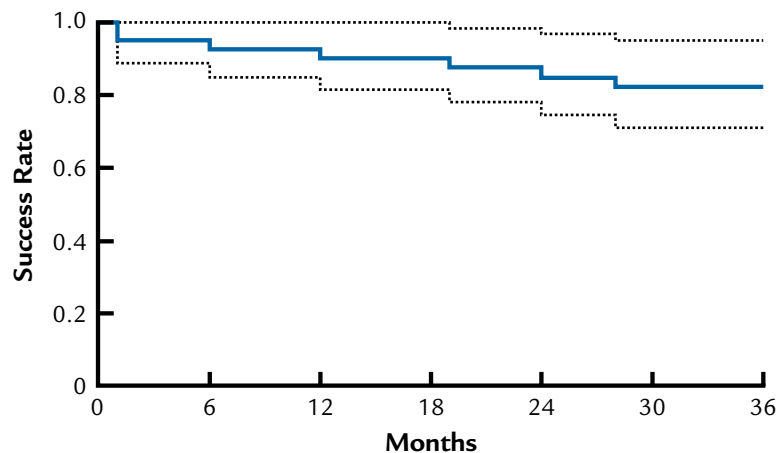
3 Success rate of CAD/CAM titanium ceramic crown over 3 years by Kaplan-Meier cumulative analysis with 95% confidence interval.
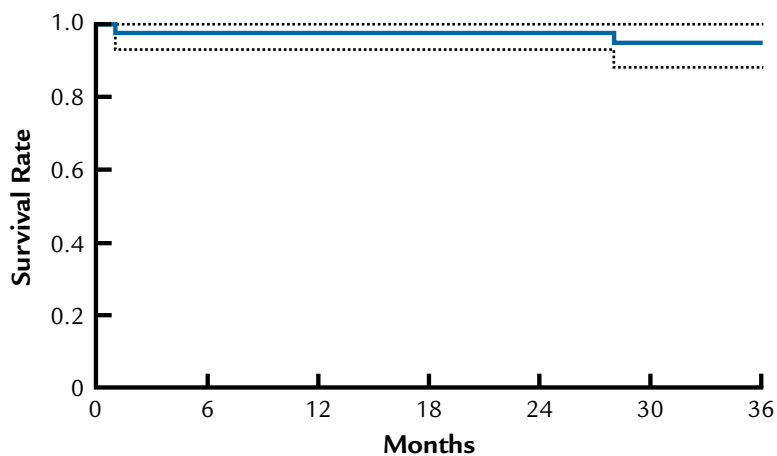
4 Kaplan-Meier cumulative survival rate with 95% confidence interval of CAD/CAM titanium ceramic crown over 3 years.

with BOP also increased initially, but there was no increase at 12 (PI) or 24 months (BOP). No deterioration in the shade of the veneering porcelain was observed during the recall examinations.

Three patients (1 anterior and 2 posterior crowns) did not return at the 12-month follow-up due to a medical condition (n=2) or inability to locate (n=1) and were withdrawn from the study. Therefore, the success rate of CAD/CAM titanium ceramic crowns with regard to the mechanical complications was 82.3% (95% confidence interval: 71.2% to 95.1%) by the Kaplan-Meier cumulative survival analysis (Fig. 3). The cumulative survival rate of the crown was 94.9% (95% confidence interval: 88.3% to 100%) after 3 years (Fig. 4).

DISCUSSION

The first null hypothesis, that the CAD/CAM titanium ceramic crowns would function intraorally with no mechanical complications for 3 years, was rejected, as the success rate of CAD/CAM titanium ceramic crowns with regard to the mechanical complications demonstrated a 95% confidence interval from 71.2% to 95.1%. The second hypothesis, that the CAD/CAM titanium ceramic crowns would survive intraorally without replacement for 3 years, was not rejected, as the 95% confidence interval of the survival rate of the crown was from 88.3% to 100%.

The present clinical study demonstrated that the CAD/CAM titanium ceramic single crowns developed several veneering porcelain fractures, primarily for the posterior crowns. This finding was not consistent with the outcomes of previous studies that investigated the conventional metal ceramic system. Walton[2] reported significantly higher retreatment needs for anterior metal ceramic crowns than posterior. However, the retreatment was primarily linked to biologic complications such as caries or root fracture, not to mechanical problems. Also, De Backer et al[4] reported a higher survival rate for metal ceramic crowns on molars compared to premolars or anterior teeth. Since the differences were not significant, the authors did not explain the rationale for the finding. However, biologic complications were responsible for most of the failures. The findings from the present CAD/CAM titanium ceramic study indicate that heavy occlusal force was related to the incidence of porcelain fracture. With regard to the classification of the porcelain fracture, both cohesive (Class III) and adhesive (Class IV) failures were observed. Therefore, the bond strength between titanium and porcelain may have been insufficient to resist the occlusal force at the posterior region, or the lack of metal support resulting from the use of the nonanatomic

coping could have resulted in the cohesive porcelain failure in the area where shear occlusal force occurred. For example, the porcelain fractures were observed on the proximal marginal ridges or distolingual cusps of mandibular molars. Even though the CAD/CAM titanium ceramic crowns showed a clinically acceptable survival rate of approximately 95%, they may not be recommended for areas where heavy occlusal forces are anticipated, to minimize the incidence of mechanical complications.

As for the frequency of the mechanical complications, it was found that the success rate according to the Kaplan-Meier cumulative survival analysis (82.3%) was lower than reported success rates of other studies that investigated porcelain titanium crowns fabricated by former methods (copy milling and spark erosion). These studies reported that the incidence of porcelain fracture was small,[22,23,27] or 6%[26] out of the entire group. Since the system used for the present study was new, there may be a learning-curve factor influencing the results. Although the incidence of porcelain fracture occurred as long as 28 months after cementation, almost half of the porcelain fractures occurred within the first 6 months. This phenomenon may have resulted from flaws included during the crown fabrication process that went unnoticed. As the CAD/CAM system for fabricating the titanium ceramic crowns was a newly developed system, more flaws could have been incorporated in the crowns due to insufficient experience of clinicians and laboratory technicians. Other patient factors such as parafunctional habits or excessive occlusal forces that were not carefully screened in the beginning may also have resulted in those early failures. Therefore, to verify that the porcelain failures of CAD/CAM titanium ceramic crowns occur more frequently earlier in function, and to determine the causes of the failures, a follow-up study for a longer duration is indicated. Furthermore, the coping

could have been fabricated in an anatomic form by the copy milling technique, whereas the CAD/CAM technique used in the current study was capable of fabricating only copings with an even thickness (nonanatomic form). The difference in support for the veneering porcelain could have resulted in different incidences of mechanical complications. As described previously, the crowns with veneering porcelain fracture were managed by procedures ranging from simple polishing to repairing using composite resin, according to the severity of the incidence. Unfortunately, 2 crowns showed significant loss of function that resulted in replacement (failure), as they could not be repaired.

It was found that the CAD/CAM titanium ceramic crowns did not have any biologic complications. The fit of the crowns was confirmed to be acceptable at the time of insertion and did not demonstrate open or defective margins during the 3-year observation period. The periodontal parameters appeared to increase in severity over time, but the increase either diminished or was eliminated during the later stages of follow up. The mean probing depth was maintained at 3 mm, and approximately 30% of surfaces showed bleeding on probing at the end of the observation period. A similar trend was found in an earlier study that investigated titanium ceramic crowns made using previous fabrication methods (copy milling, spark erosion, and low-fusing porcelain) over 5 years.[26] It was also reported in a literature review article that conventional restorations could cause slight gingival inflammation regardless of the quality of the restorations.[41] Therefore, the authors of the present study believe that the effect of the CAD/CAM titanium ceramic crown on periodontal tissues after 3 years of use was minimal and comparable to other restorative systems. Nonetheless, since the probing depth remained increased at the end of the study, it was not clear whether the PD would constantly increase in the

future or not. A continuous follow-up study is suggested to confirm the long-term effect of the CAD/CAM titanium ceramic crown on periodontal health.

The shade of the veneering porcelain in all crowns remained stable for 3 years. Considering that deteriorating esthetics due to unstable shades and rough surfaces were the primary problems of the previous low-fusing porcelains,[22,25] the present study demonstrated an improvement in color stability.

A limitation of the present study was that the newly developed restorative system was tested in vivo without a control group. It should be noted that, even though this preliminary report provided 3-year follow up results, the comparisons with other restorative systems were made only indirectly thorough literature review. Also, 3 years may not be long enough to understand all of the aspects of the clinical behaviors of a certain restorative system. These factors should be considered when the CAD/CAM titanium ceramic crowns are to be used in clinical practice.

Even though the CAD/CAM titanium ceramic crowns generally performed well, the authors believe that the nonanatomic coping may have affected the incidence of the mechanical complications. With the advancements in CAD/CAM systems, a similar clinical study to observe clinical performances of CAD/CAM titanium ceramic crowns with anatomic copings is indicated.

CONCLUSIONS

Within the limitations of the present study, it was concluded that the clinical performances of CAD/CAM titanium ceramic crowns over 3 years were acceptable, with no biologic complications and a high cumulative survival rate. However, porcelain fracture occurred frequently, and some restorations were not repairable and needed to be remade.

REFERENCES

1. Valderhaug J. A 15-year clinical evaluation of fixed prosthodontics. Acta Odontol Scand 1991;49:35-40.
2. Glantz PO, Nilner K, Jendresen MD, Sundberg H. Quality of fixed prosthodontics after twenty-two years. Acta Odontol Scand 2002;60:213-8.
3. Pjetursson BE, Tan K, Lang NP, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. Clin Oral Implants Res 2004;15:625-42.
4. De Backer H, Van Maele G, De Moor N, Van den Berghe L, De Boever J. An 18-year retrospective survival study of full crowns with or without posts. Int J Prosthodont 2006;19:136-42.
5. Pjetursson BE, Sailer I, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns. Clin Oral Implants Res 2007;18 Suppl 3:73-85.
6. Wang RR, Fenton A. Titanium for prosthodontic applications: a review of the literature. Quintessence Int 1996;27:401-8.
7. Nakajima H, Okabe T. Titanium in dentistry: development and research in the U.S.A. Dent Mater J 1996;15:77-90.
8. Tschernitschek H, Borchers L, Geurtsen W. Nonalloyed titanium as a bioinert metal--a review. Quintessence Int 2005;36:523-30.
9. Koike M, Cai Z, Fujii H, Brezner M, Okabe T. Corrosion behavior of cast titanium with reduced surface reaction layer made by a face-coating method. Biomaterials 2003;24:4541-9.
10. Sung SY, Kim YJ. Alpha-case formation mechanism on titanium investment castings. Mater Sci Eng A 2005;405:173-7.
11. Adachi M, Mackert JR Jr, Parry EE, Fairhurst CW. Oxide adherence and porcelain bonding to titanium and Ti-6Al-4V alloy. J Dent Res 1990;69:1230-5.
12. Kimura H, Horng CJ, Okazaki M, Takahashi J. Oxidation effects on porcelain-titanium interface reactions and bond strength. Dent Mater J 1990;9:91-9.
13. Sunnerkrantz PA, Syverud M, Herö H. Effect of casting atmosphere on the quality of Ti-crowns. Scand J Dent Res 1990;98:268-72.
14. Tajima K, Matsuda S, Kitajima S, Yokoyama Y, Kakigawa H, Kozono Y. Efficacy of gas purging for titanium casting. Dent Mater J 1994;13:206-13.
15. Kikuchi H, Onouchi M, Hsu HC, Kurotani T, Nishiyama M. Titanium casting: the surface reaction layer of castings obtained using ultra-low-temperature molds. J Oral Sci 2001;43:27-33.
16. Luo XP, Guo TW, Ou YG, Liu Q. Titanium casting into phosphate bonded investment with zirconite. Dent Mater 2002;18:512-5.
17. Sadeq A, Cai Z, Woody RD, Miller AW. Effects of interfacial variables on ceramic adherence to cast and machined commercially pure titanium. J Prosthet Dent 2003;90:10-7.
18. Andersson M, Bergman B, Bessing C, Ericson G, Lundquist P, Nilson H. Clinical results with titanium crowns fabricated with machine duplication and spark erosion. Acta Odontol Scand 1989;47:279-86.
19. Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J 1993;43:245-53.
20. Togaya T, Suzuki M, Tsutsumi S, Ida K. An application of pure titanium to the metal porcelain system. Dent Mater J 1983;2:210-9.
21. Kvam K, Derand T, Austrheim EK. Fracture toughness and flexural strength of dental ceramics for titanium. Biomaterials 1995;16:73-6.
22. Nilson H, Bergman B, Bessing C, Lundqvist P, Andersson M. Titanium copings veneered with Procera ceramics: a longitudinal clinical study. Int J Prosthodont 1994;7:115-9.
23. Milleding P, Haag P, Neroth B, Renz I. Two years of clinical experience with Procera titanium crowns. Int J Prosthodont 1998;11:224-32.
24. Bergman B, Nilson H, Andersson M. A longitudinal clinical study of Procera ceramic-veneered titanium copings. Int J Prosthodont 1999;12:135-9.
25. Bergman B, Marklund S, Nilson H, Hedlund SO. An intraindividual clinical comparison of 2 metal-ceramic systems. Int J Prosthodont 1999;12:444-7.
26. Lövgren R, Andersson B, Carlsson GE, Odman P. Prospective clinical 5-year study of ceramic-veneered titanium restorations with the Procera system. J Prosthet Dent 2000;84:514-21.
27. Marklund S, Bergman B, Hedlund SO, Nilson H. An intraindividual clinical comparison of two metal-ceramic systems: a 5-year prospective study. Int J Prosthodont 2003;16:70-3.
28. Persson M, Andersson M, Bergman B. The accuracy of a high-precision digitizer for CAD/CAM of crowns. J Prosthet Dent 1995;74:223-9.
29. Priest G. Virtual-designed and computer-milled implant abutments. J Oral Maxillofac Surg 2005;63 (9 Suppl 2):22-32.
30. Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. J Am Dent Assoc 2006;137:1289-96.
31. Persson M, Andersson M, Bergman B. The accuracy of a high-precision digitizer for CAD/CAM of crowns. J Prosthet Dent 1995;74:223-9.
32. Andersson M, Carlsson L, Persson M, Bergman B. Accuracy of machine milling and spark erosion with a CAD/CAM system. J Prosthet Dent 1996;76:187-93.
33. Willer J, Rossbach A, Weber HP. Computer-assisted milling of dental restorations using a new CAD/CAM data acquisition system. J Prosthet Dent 1998;80:346-53.
34. Witkowski S, Komine F, Gerds T. Marginal accuracy of titanium copings fabricated by casting and CAD/CAM techniques. J Prosthet Dent 2006;96:47-52.

35. Tan PL, Gratton DG, Diaz-Arnold AM, Holmes DC. An in vitro comparison of vertical marginal gaps of CAD/CAM titanium and conventional cast restorations. J Prosthodont 2008;17:378-83.

36. Hobo S, Shillingburg HT Jr. Porcelain fused to metal: tooth preparation and coping design. J Prosthet Dent 1973;30:28-36.

37. Moher D, Schulz KF, Altman DG. The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomised trials. Lancet 2001;357:1191-4.

38. Silness J, Loe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 1964;22:121-35.

39. Listgarten MA. Periodontal probing: what does it mean? J Clin Periodontol 1980;7:165-76.

40. Newman MG, Takei H, Klokkevold PR, Carranza FA. Carranza's clinical periodontology. 10th ed. St. Louis: Elsevier; 2006. p. 553.

41. Knoernschild KL, Campbell SD. Periodontal tissue responses after insertion of artificial crowns and fixed partial dentures. J Prosthet Dent 2000;84:492-8.

Corresponding author:
Dr Arne Boeckler
Poliklink für Prothetik
Grosse Steinstrasse 19
06108 Halle (Saale)
GERMANY
Fax: +49 345 557 3798
E-mail: arne.boeckler@medizin.uni-halle.de

NOTEWORTHY ABSTRACTS OF THE CURRENT LITERATURE

Prosthetic screw detorque values in implants retained as cast bar superstructures or bars modified by the Cresco Ti Precision technique-- A comparative in vivo study

Schmitt J, Holst S, Eitner S, Schlegel A, Wichmann M, Hamel J.
Int J Prosthodont 2009;22:193–200.

Purpose: This prospective clinical trial investigated the effect of different fabrication techniques on screw-joint stability in implant-retained frameworks.

Materials and Methods: Seventy-nine dental implants (39 Branemark System and 40 Straumann) were inserted into 20 patients with an edentulous mandible. One of two fabrication techniques was randomly chosen as a definitive restoration, either a cast bar or a bar superstructure modified with the Cresco Ti Precision (CTiP) technique. The patients were divided into four groups depending on the type of implant and prosthetic superstructure: Straumann-conventional (Sc), Straumann-Cresco (SCr), Branemark-conventional (Bc), and Branemark-Cresco (BCr). Initial torque values and removal torque values were recorded with a custom-made digital torque controller both 1 week (T1) and 3 months (T2) after clinical function.

Results: Statistical analysis revealed significant differences in absolute detorque values at T1 ($P = .002$) with 4.51 Ncm (SD = 3.80) for the Sc group, 10.65 Ncm (SD = 4.42) for SCr, 11.24 Ncm (SD = 4.00) for Bc, and 9.02 Ncm (SD = 3.81) for BCr. At T2 ($P = .000$) the median values of lost torque were 5.08 Ncm (SD = 4.05) for the Sc group, 10.51 (SD = 3.00) for SCr, 7.50 (SD = 5.86) for Bc, and 9.41 Ncm (SD = 4.54) for BCr. However, when correlation of detorque values to initial torque values was performed, no statistical differences were found between groups or time points. The percentage of lost torque at T1 ($P = .849$) and T2 ($P = .058$) was 28.60% (SD = 21.80) and 32.85% (SD = 24.65), 30.04% (SD = 12.49) and 30.80% (SD = 8.66), 32.11% (SD = 11.37) and 21.03% (SD = 16.53), and 25.33% (SD = 10.69) and 27.83% (SD = 12.57) for the Sc, SCr, Bc, and BCr groups, respectively.

Conclusions: The screw-joint stability of passivated bars is not superior to cast superstructures. A general decrease of approximately 30% of initial torque values can be expected in clinical situations, independent of the implant system used.

Reprinted with permission of Quintessence Publishing.