Clinical Performance of One-Piece, Screw-Retained Implant Crowns Based on Hand-Veneered CAD/CAM Zirconia Abutments After a Mean Follow-up Period of 2.3 Years

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Purpose: The aim of this study was to evaluate the clinical performance of one-piece, screw-retained implant crowns based on hand-veneered computer-aided design/computer-aided manufacture (CAD/CAM) zirconium dioxide abutments with a crossfit connection at least 1 year after insertion of the crown. Materials and Methods: Consecutive patients who had received at least one Straumann bone level implant and one-piece, screw-retained implant crowns fabricated with CARES zirconium dioxide abutments were reexamined. Patient satisfaction, occlusal and peri-implant parameters, mechanical and biologic complications, radiologic parameters, and esthetics were recorded. Results: A total of 50 implant crowns in the anterior and premolar region were examined in 41 patients. The follow-up period of the definitive reconstructions ranged from 1.1 to 3.8 years. No technical and no biologic complications had occurred. At the reexamination, 100% of the implants and reconstructions were in situ. Radiographic evaluation revealed a mean distance from the implant shoulder to the first visible bone-to-implant contact of 0.06 mm at the follow-up examination. Conclusion: Screw-retained crowns based on veneered CAD/CAM zirconium dioxide abutments with a crossfit connection seem to be a promising way to replace missing teeth in the anterior and premolar region. In the short term, neither failures of components nor complications were noted, and the clinical and radiographic data revealed stable hard and soft tissue conditions. Int J Oral Maxillofac Implants 2018;33:188–196. doi: 10.11607/jomi.5929

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During the last 30 years, computer-aided design (CAD) and computer-aided manufacturing (CAM) have evolved significantly.¹ These new technologies allowed processing of zirconium dioxide and consequently established the material in dental medicine.² It has not been possible before to use high-strength ceramics due to the lack of machining in the dental laboratory. Consequently, the skills of dental technicians had to be adapted, and several work processes are now supported by computers and software, eg, the outline of a part or even the entire reconstruction.³ The esthetic expectations of patients and the ambition of dentists to counterbalance the rising gold price led to an increased interest in all-ceramic reconstructions.⁴,⁵ Zirconia is meanwhile routinely used for frameworks of crowns and fixed dental prostheses (FDPs), monolithic crowns and FDPs, frameworks of resin-bonded FDPs, implant abutments, implants, or even removable prostheses. CAD/CAM has, therefore, opened new avenues for clinical applications and forced the traditional suppliers to diversify into new technologies.⁶ The advantages of zirconia implant abutments include the individualized design for better soft tissue integration and favorable esthetics.⁷⁻⁸ Compared with titanium or gold abutments, all-ceramic abutments...
have a more natural appearance, especially in the presence of a thin mucosal biotype. 

Animal studies revealed more favorable tissue reactions in contact with titanium and ceramic compared with gold. In human studies, reduced bacterial adhesion on zirconia compared with titanium abutments could be documented. 

Implant crowns can be screw-retained or cemented. As early as 2004, 4-year results of zirconia abutments with cemented all-ceramic crowns showed promising results in the anterior region. Recent studies on the clinical performance of customized zirconia abutments of single implant crowns are scarce but seem to confirm the assumption. Surprisingly, most of the existing literature on zirconia abutments evaluates abutments with cemented all-ceramic crowns. Despite the fact that one-piece, screw-retained ceramic crowns are preferred by many clinicians and are routinely used, especially in the esthetic zone, there are few clinical reports available related to this type of implant crown.

Zirconia abutments can also be directly veneered and consequently screw-retained as a one-piece reconstruction, provided that the implants were placed according to a prosthetically driven concept. As a prerequisite for this type of reconstruction, the framework has to be designed anatomically to support the veneering ceramic.

A big advantage of screw retention is the absence of an interface to be filled with cement. Clinically, it is almost impossible to remove all cement remnants after cementation. Those remnants can lead to biologic complications, which occur more often in cement-retained reconstructions. Other advantages of screw retention include the ease of retrievability and the simple handling of only one component, which has to be screwed or unscrewed at try-ins and the final insertions of the reconstruction.

Implants and abutments exist in various designs related to their interfaces. Clinical studies demonstrated less screw loosening with internal connections compared with external connections in both zirconia and ceramo-metal implant crowns. This leads to the assumption that internal connections are superior. However, every system has its own biomechanical characteristics. The same type of abutment in two implant systems can result in completely different outcomes. Diverse diameters, different rotational freedom or precision of fit, the shape of the abutment screw, material combinations, torque, and many more parameters influence the stability of the connection. The performance of every system has to be evaluated separately. Nonoriginal abutments especially seem to be less precise and show more micromotion in laboratory studies.

Furthermore, there is increasing evidence that the zirconia abutments may lead to abrasion of the internal part of the titanium implants. This may lead to more rotational freedom and to mucosal discoloration because of titanium particles in the peri-implant mucosa. Even if the clinical relevance remains unclear so far, it seems obvious that damage of the internal part of the titanium implant may lead to prosthetic complications, and in the worst case, the implant has to be removed.

The aim of this study was to evaluate the clinical performance as well as the biologic and technical complications to be expected with screw-retained, one-piece crowns. All crowns were fabricated based on CAD/CAM zirconia abutments with an original crossfit connection. Moreover, patient satisfaction, esthetics, and the risk of tissue tattoos were analyzed.

**MATERIALS AND METHODS**

**Patient Recruitment**

The study was approved by the Ethics Committee Bern (KEK-Nr. 020/13). The charts of all patients who had received a Straumann bone level implant (Straumann AG) reconstructed with a one-piece, screw-retained, directly veneered zirconia crown between January 2009 and March 2012 were collected. A total of 41 consecutive patients with 50 implant crowns received an appointment for the follow-up examination. Prior to the follow-up examination, patients received detailed information (spoken and written) about the study procedures. All patients agreed to attend and gave their written consent.

The exclusion criteria comprised pregnancy at the time of the follow-up examination (zero patients), a mental handicap (one patient), and the need of antibiotic prophylaxis prior to a clinical examination (zero patients).

**Implants and Reconstructions**

All implants were Straumann bone level implants (Straumann AG) with a NC (Narrow CrossFit) or RC (Regular CrossFit) connection and a SLActive surface. Guided bone regeneration (GBR), sinus floor elevation, or block grafts were performed when needed. Dentists of the Division of Fixed Prosthodontics or Department of Oral Surgery at the University of Bern placed the implants, and all patients were referred to the Division of Fixed Prosthodontics for the fabrication of the crown. At the time point of the implant placement, all patients were periodontally healthy (no residual pockets > 4 mm). Patients with periodontal problems underwent systematic initial therapy prior to implant surgery. Heavy smokers exceeding 15 cigarettes per day did not receive implants at the involved institutions.
The reconstructions were one-piece, screw-retained implant crowns fabricated with CARES zirconium dioxide abutments (Straumann), which were directly veneered with hand-layering.

Four different technicians collaborating on a regular basis with the Division of Fixed Prosthodontics fabricated the implant crowns. Provisional crowns were inserted when considered necessary to improve the emergence profile. All definitive reconstructions were one-piece, screw-retained implant crowns fabricated with CARES zirconium dioxide abutments (Straumann AG) directly veneered (Fig 1). The veneering ceramic was hand-layered. Three different veneering ceramics had been used, depending on the dental laboratory. Twenty-nine abutments were hand-layered with IPS e.max Ceram (Ivoclar Vivadent), 14 with Noritake Cerambien ZR (Kuraray), and 7 with Vita VM9 (Vita Zahnfabrik). The abutment screws of the definitive reconstructions were tightened with a ratchet to a torque of 35 Ncm according to the manufacturer’s guidelines. Screw access holes were closed with a polytetrafluoroethylene tape and resin-based composite.

Follow-up Examination
The follow-up examinations consisted of four parts (questionnaire, clinical examination, photographs, radiographs) and were performed by the authors between June 2013 and July 2014.

Patients were asked to fill out a questionnaire about their current recall interval, oral hygiene and smoking habits, awareness of bruxism, and incidents of complications. Satisfaction of treatment in terms of function and esthetics was judged by using two visual analog scales (VAS). Patients were asked to rate their satisfaction with a number from 1 to 10, where 1 means poor and 10 means excellent.

Specific data such as date of implant placement, details on bone augmentation, the date of insertion of the definitive reconstruction, and the type of veneering ceramic were collected from the patient’s chart. The clinical examination included technical, functional, biologic, and aesthetic parameters as follows.

To detect technical complications such as screw loosening and abutment fractures, the implant crown was examined manually to notice movements of the reconstruction. To recognize even minor chippings or cracks, the crowns were illuminated with a polymerization light (Bluephase G2, Ivoclar Vivadent). The visual inspection was performed with magnifying glasses with a magnification of 2.5×. The quality of the composite closing was inspected with a dental mirror and a dental probe (DMS dental mirror and DH2 probe, Deppeler SA).

Functional parameters included the presence or absence of guidance and the presence of centric and eccentric contacts between the reconstruction and the opposing teeth using shimstock foil (Coltène/Whaledent AG) and articulating paper (Hanel Articulating Paper 40 µm, Coltène/Whaledent AG). The presence of attrition in general and traces on the crowns were noted. The presence and type of reconstructions in the opposing dentition were recorded.

The peri-implant conditions were assessed with a periodontal probe (HH12 periodontal probe, Deppeler SA) at six aspects per implant (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, distolingual). Probing pocket depth (PPD), bleeding on probing (BOP), and the presence or absence of plaque (Plaque Index [PI]) were recorded. Visible food impaction was noted. The mucosa was inspected carefully (for example, for presence of fistulas and discoloration), and the midbuccal width of the keratinized mucosa was measured.

Esthetics was evaluated according to the pink and white esthetic score (PES/WES) by Fürhauser et al, which was modified by Belser et al.

Photographs of all reconstructions were obtained from the frontal, lateral, and occlusal views.

From every implant crown, a standardized periapical radiograph was taken with the parallel technique. To obtain a standardized situation for future investigations, film holders (XCP Dentsply Rinn) were individualized with pattern resin (GC Pattern Resin, LS GS Corporation).

The radiographs of the follow-up examination, as well as existing radiographs from the time points of implant placement and delivery of the reconstruction, were evaluated by one dentist (N.S.). The distance between the implant shoulder and the bone crest (in the direction of implant axis) or the first visible bone-to-implant contact and the implant shoulder (distance implant-bone [DIBI]) was measured mesially and distally by using ImageJ software (ImageJ, National Institutes of Health, version 1.48u4). Before the measurements were obtained, all images were scaled based on the known thread height of 0.8 mm as a reference.

Statistical Analysis
Data were presented using descriptive statistics. The pooled mesial and distal crestal bone levels obtained at implant placement, delivery of the crown, and at the reevaluation were statistically compared. Boxplots

Fig 1 The reconstructions were one-piece, screw-retained implant crowns fabricated with CARES zirconium dioxide abutments (Straumann), which were directly veneered with hand-layering.
were drawn to illustrate the empirical distribution of the three different time points.

Nonparametric methods were chosen after checking data for normality by the Shapiro-Wilk test (P < .0001, indicating nonnormal distributed data).

Simultaneous comparisons between three samples were done performing Friedman tests if they were paired and Kruskal-Wallis tests otherwise. Two samples were compared with Wilcoxon signed rank tests if they were paired and otherwise with Wilcoxon-Mann-Whitney tests.

To assess the correlation between the PES/WES scores and the patient VAS scores for esthetic satisfaction, Spearman rank correlation coefficients were calculated. All statistical results were calculated with R 3.2.2 (R Foundation for Statistical Computing).

No correction for multiple testing was applied due to the explorative nature of this study. P values less than .05 were regarded as indicating statistical significance.

RESULTS

Questionnaire and Patient History

Forty-one patients (28 women and 13 men) with 50 single implant crowns participated in this follow-up examination. Most of the reconstructions were located in the maxilla (44) and only 6 in the mandible; 18 premolars, 4 canines, and 28 incisors were examined. The implant positions and the type of implant placement are listed in Fig 2. Thirty-four patients had received one single crown, five had received two single crowns, and two had received three single crowns. The age of the patients ranged from 22 to 81 years (mean: 46.4 years). Twenty-nine were nonsmokers, 6 ex-smokers, and 6 smokers with a consumption of 2.5 to 40 pack years (mean: 11.4 pack years) at the time of the examination (number of pack years = [packs smoked per day] × [years as a smoker]). None of the patients smoked more than 15 cigarettes per day. Provisional crowns were inserted on 36 implants (26 maxillary incisors, two maxillary and one mandibular canine, six maxillary and one mandibular premolar) and had been in function between 63 and 552 days (mean: 212 days).

The follow-up period of the definitive reconstruction ranged from 1.1 to 3.8 years (mean follow-up: 2.3 years). Most of the patients participated in a yearly supportive therapy program (53.7%), 36.6% visited the dental hygienist twice a year, 2.4% every second year, and 7.3% did not participate in any recall; 28.8% of the patients reported having parafunctional habits, whereas 71.2% had none or were not aware of them, but only 4.8% used a protective splint.

Clinical Evaluation

The survival rates for the implants and the crowns of the 41 patients were 100%. Neither abutment or screw fracture, nor loosening of the abutment screw nor chipping had occurred. One patient showed an insufficient resin-based composite cover. All other closures were sufficient. Nine patients (18.4%) presented a discoloration of the cover, 24 patients (49%) only a marginal discoloration, and 16 patients (32.6%) revealed no discolorations at all.

Forty-two percent of the implant crowns revealed centric occlusal contacts, whereas 58% showed none. Eccentric contacts and consequently guidance existed in 50% of the reconstructions. Antagonist teeth were natural teeth in 78%. Two were restored with amalgam (4%) and three with resin-based composite (6%), whereas four were abutment teeth for crowns or FDPs (8%), and two implant-supported fixed reconstructions (4%).

The results of the clinical examination are presented in Fig 3. The distribution of the PPDs revealed that at 291 sites (97%), the PPD was ≤ 4 mm, at six sites (2%) 5 mm, and at three sites (1%) 6 mm.

The implant crowns were properly cleaned (PI of 1.4/10 mm) for 36 implants (26 maxillary incisors, two maxillary and one mandibular canine, six maxillary and one mandibular premolar) and had been in function between 63 and 552 days (mean: 212 days).
by at least 1 mm of keratinized mucosa. At most of the implants (50%), a width of 3 mm of keratinized mucosa was measured.

The PES/WES could only be performed in 21 crowns. In all the other sites, the contralateral teeth had either been reconstructed with implants and crowns (13 patients), crowns (9 patients), or were restored with large fillings. In this sample of 21 crowns, the PES ranged from 4 to 9 with a median of 7 and the WES from 1 to 9 (median: 7) (Fig 4).

**Radiographic Evaluation**

The pooled mesial and distal distances from the crestal bone levels in relation to the implant shoulder at the time of implant placement, delivery of the reconstruction, and the follow-up examination are presented in Fig 5. Negative values represent a bone level coronal to the implant platform, whereas positive values indicate a crestal bone loss.

At the time of implant placement, a mean distance from the implant shoulder to the bone crest of –0.95 mm (95% confidence interval [–2.39, 0.48])...
was measured (Fig 6). At delivery of the crown, the measurements were –0.13 mm (95% confidence interval [–1.12, 0.87]). During the follow-up visit, the mean distance from the implant shoulder to the first bone-to-implant contact was 0.06 mm (95% confidence interval [–0.58, 0.70]).

Overall, between implant placement and delivery of the reconstruction, initial remodeling occurred. Between the delivery and the follow-up examination, only minor changes were noted. The coronal bone-to-implant contact stabilized in most of the situations at the implant shoulder (arrows). At the time of follow-up, minor marginal bone loss from the implant shoulder was visible.

**Patient Satisfaction**

The VAS evaluation revealed a mean esthetic satisfaction of 9.5 (out of 10) with a range from 7 to 10 and a mean functional satisfaction of 9.3 (out of 10) with a range from 6 to 10 (Fig 8). The esthetic satisfaction of patients (questionnaire) and the clinical evaluation with the PES/WES correlated poorly (Spearman rank correlation coefficient) (PES and esthetics = 0.2156; WES and esthetics = 0.2696).

The main complaint of patients in the questionnaire was food impaction, concerning seven patients (16%). These patients showed partially or completely missing papillae. Two patients complained about the roughness of the resin-based composite closing and one about bleeding of the mucosa.

**DISCUSSION**

A 100% survival rate for the implants and the crowns was noted, and no technical and no biologic complications had occurred. The examined implant crowns had been in function for at least 1.1 year and up to 3.8 years. These results are very promising, but the observation period is short.

Six-year results of bone level implants in the esthetic zone after contour augmentation revealed similar data with a survival and success rate of 100%. In a recent systematic review, the estimated failure rate of screw-retained reconstructions per 100 at risk per year was 0.91 (0.57 to 1.46). In addition, the cemented all-ceramic reconstructions demonstrated a higher failure rate compared with the cemented ceramo-metal
reconstructions \((P = .01)\). This difference, however, was not found when full-ceramic screw-retained reconstructions and ceramo-metal screw-retained reconstructions were compared \((P = .66)\).22

Surprisingly, in the present study, no chippings were found. It has to be mentioned that centric occlusal contacts existed in 42% and eccentric contacts in 50% of the reconstructions. Earlier studies comparing ceramo-metal crowns and veneered zirconia crowns on teeth revealed a higher chipping rate for all-ceramic reconstructions.33 One would suppose to find even more fractures on implant-supported single-tooth reconstructions due to the reduced proprioception and lack of shock absorption compared with teeth.34

A systematic review compared the current literature of metal-ceramic and zirconia-based FDPs and found no statistical significance between the chipping rates of those materials. They concluded that the gained and transferred knowledge as well as earlier ignorance might be the reason.35

Other studies on zirconia abutments in the anterior and premolar region identified two minor chippings in 52 reconstructions after 3 years of function36 or no fractures after 5 years of function,15 similar to the findings of the present study.

A rather high chipping rate of 22% was noted in a 3-year follow-up examination of prefabricated zirconia abutments with cemented implant crowns.37 It has to be considered that all these reconstructions had been located in the posterior area, which might be a reason for the high chipping rate.

Concerning the issue of abutment fracture, diameter-reduced implants especially are of interest. A 5-year follow-up study on cemented all-ceramic implant crowns in the anterior region showed no abutment fracture.38 In the present study, also, no abutment fractures were found, which might be due to the reasonably wide cross-section dimension of the abutments even in the diameter-reduced implants.

A retrospective long-term study compared different implant systems restored with customized zirconia abutments and found differences in the clinical performance of the abutments depending on the implant system.39 In this study, the Straumann BL design showed high survival rates and no abutment fracture, whereas other systems showed higher complication rates, including abutment fractures.39

Only a minor mean crestal bone loss with respect to the implant platform was observed. At follow-up, a mean distance of 0.06 mm from the implant shoulder to the first visible bone-to-implant contact was measured.

Comparing this number to the data in the literature, similar rates had been reported. For example, implants restored with single crowns in the esthetic zone revealed a mean bone loss of 0.18 mm after 3 years.40

As the implants were placed approximately 1 mm \((-0.95 \text{ mm [95% confidence interval } (-2.39, 0.48)])\) below the crestal bone level, the overall bone remodeling from implant placement to the follow-up visit was 1.01 mm. All implants were placed according to the recommended distance of at least 1.5 mm from the implant shoulder to the neighboring teeth.41 Therefore, the bone level at the adjacent teeth was minimally affected by remodeling, but the gradient of bone crest between the adjacent teeth and implants got steeper (Figs 6 and 7).

The radiographic data need to be interpreted with caution. First of all, the radiographs obtained at the time of implant placement and delivery of the definitive reconstructions were not standardized. Moreover, the interpretation of the radiograph is subjective and can differ from observer to observer.

The main complaint as noted in the questionnaires was food impaction (16%) associated with partially or completely missing papillae. Most of these patients were already used to cleaning with interdental brushes and got consequently used to the situation. The second most frequent complaint was the roughness of the resin-based composite closing, concerning three patients. Two fillings were polished, and one closing was redone.

In terms of esthetics, a questionnaire combined with a VAS was applied to rate the patient's opinion. PES/WES was used to rate the esthetic appearance according to the raters. Surprisingly, patient satisfaction did not correlate at all with the PES/WES. One dentist was responsible for all these ratings. The PES/WES values were rather low since the responsible scorer has applied a strict evaluation. Although the PES/WES is reported to be one of the more reproducible ratings,42 it does not seem to reflect the patient's opinion and can be dependent on subjective differences between observers.

In the fabrication process of the crowns in the present study, original components were used. A prospective cohort study investigated nonoriginal alumina-toughened zirconia abutments on different implant systems.43 The estimated cumulative complication rate after 5 years was 19.7%, which is rather high. One has to consider that 96% of those complications occurred in the posterior area.

According to a recent systematic review comparing the performance of screw- versus cement-retained fixed implant-supported reconstructions, cement-retained reconstructions demonstrate significantly more biologic complications.22 In the present study, there were no biologic complications, and no suppuration and no fistula were found.
Recent case reports described the phenomenon of “tissue tattooing” associated with a loosening of the abutment screw. In an in vitro study, the wear at the interface was investigated. Higher wear on titanium implants with zirconia abutments was measured compared to titanium implants with titanium abutments.

In the present study, no mucosal discoloration around the implants was visible and no loosening of the definitive reconstruction detected. Moreover, the longest follow-up period was only 3.8 years. It has to be considered that after the first try-in, traces of titanium can be seen on these abutments. Therefore, it will be interesting to look at the same aspect after 5 and 10 years.

The ITI consensus statement of 2014 regarding restorative materials and techniques for implant dentistry reports no difference between ceramic and metal abutments in the clinical performance, but also mentions that caution in molar sites is recommended. The wide variety of different zirconium abutments was indicated, and its different performances were pointed out. The recommended indication was limited to the anterior and premolar region. The short-term results of the present study underline the good performance in the aforementioned regions. Future investigations and especially long-term data will be of great interest.

CONCLUSIONS

Screw-retained implant crowns based on veneered CAD/CAM zirconium dioxide abutments with a cross-fit connection seem to be a promising way to replace missing teeth in the anterior and premolar region.

Neither failures nor complications of components were observed over a mean observation period of 2.3 years.

Clinical and radiographic data revealed stable hard and soft tissue conditions.

PES/WES evaluation by one of the examiners did not correlate to the patients’ self-assessment.

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