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ORIGINAL ARTICLE

Retrospective and clinical evaluation of retrievable, tooth-implant supported zirconia-ceramic restorations

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Abstract

Objective. Permanent cementations of zirconia-ceramic restorations may conflict with the rationale for retrievability of implant-supported restorations. The aim of this study was to test the hypothesis that retrievable, tooth-implant supported FDPs made of veneered zirconia ceramic cores are a viable treatment alternative. ***Material and methods.*** Restorations of patients in private practice and dental clinic were evaluated by reviewing patient records retrospectively and performing a final clinical examination. Permanently cemented copings protected the tooth abutments. The zirconia-ceramic restorations were semi-permanently cemented to the copings and the implant abutments using acrylic-urethane cement. In addition to Kaplan-Meier analyses for complications, the effect of age, gender, signs of bruxism, jaw and number of units on complications was estimated using Cox regression analyses (significance $p < 0.05$). ***Results.*** The follow-up period for 23 patients (nine with signs of bruxism) with four anterior and 27 posterior zirconia-ceramic restorations (3–12 units) ranged from 12.7–47.9 months. Core fractures of two posterior prostheses in patients with signs of bruxism yielded a 40-month survival rate of 93.5%. There were 10 cohesive chippings within the veneering porcelain for seven patients (six patients with signs of bruxism), which resulted in 40-month chipping rates of 5.6% among non-bruxers and 100% among patients with signs of bruxism. The hazard ratio for signs of bruxism was 20 (95% confidence interval: 2.1–188.3, $p = 0.009$). ***Conclusions.*** Retrievable, tooth-implant supported restorations made of zirconia-ceramics should be used with caution because of some core fractures and a considerable number of minor veneer fractures. The fracture risk was very high among patients with signs of bruxism. Due to the low number of occasions for intentional retrievals, a recommendation to use semi-permanently cemented, all-ceramic FDPs would still be premature.

Key Words: *all-ceramic, dental implant, failure, fixed dental-, prosthesis*

Introduction

A combination of teeth and implants supporting a fixed dental prosthesis (FDP) is a viable treatment option [1–4]. Among other advantages such as bridging of areas with insufficient bone and cost minimization, the manifold lower threshold value for tactile perception of teeth compared to implants [5] might facilitate any occlusal adjustments and protect the prosthesis against overloading [3].

Solely implant-supported restorations are frequently either screw-retained or temporarily cemented [1,6,7] to have the option for removing of prosthetic components in cases of any technical or biological complications [4,8,9]. A retrievable design for a tooth-implant supported FDP includes the restoration of the natural abutment tooth with a double crown. The primary coping is permanently cemented to protect the prepared tooth and the secondary crown is cemented with conventional temporary cement on a zinc oxide base. The implant crown could be screw-retained or cemented with the temporary cement [1,10]. In this case, some restorations were determined to lose retention, which may cause intrusion of abutment teeth [1].

For several years, the authors of this report have used this double crown technique for the prepared teeth to temporarily (semi-permanently) cement tooth-implant supported restorations with different cements. Loss of retention following cementation with acrylic-urethane cement occurred less frequently

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than with conventional temporary cements (11.3% compared to 85% retention loss after 4 years of service) [11]. Intrusions of abutment teeth have not been observed. The acrylic-urethane cement for semi-permanent cementations was transferred to all-ceramic restorations supported by implants or by tooth–implant combinations.

Posterior FDPs comprised of older all-ceramic systems have exhibited significant failures, with a core fracture rate of ~ 2–5% per year [12]. In recent years, there have been several studies on zirconia-based FDPs supported by posterior teeth [12–15]. Fractures of zirconia cores either did not occur or occurred at a very low incidence (<1% per year). Along with other complications, such as caries, the annual failure rate for veneered zirconia FDPs of ~ 1% might be comparable to the annual failure rate for metal-ceramic FDPs that was estimated in review publications [12,13]. However, the mean incidence of minor chippings of the veneering porcelain was >3– 5% per year [12,13,15] and, thus, significantly higher than in metal-ceramic FDPs [12,15]. This was confirmed in a randomized trial [16]. Zirconia-ceramic and metal-ceramic posterior FDPs exhibited high rates of minor chipping of the veneer ceramic (zirconia-ceramic: 25%, metal-ceramic: 19%) after 3 years. An additional 8.4% of zirconia-ceramic FDPs had clinically unacceptable major chippings. The data of another clinical comparison showed that the number of fractures (chippings, cracks, crumblings, delaminations) per FDP of the veneer ceramics for zirconia was ~ 3-times higher than of the veneer ceramics for metal [17].

A few studies were published on the clinical performance of implant-supported zirconia FDPs. In a randomized trial [18], 18 patients were treated with 25 FDPs manufactured from two veneered all-ceramic cores: the milled zirconia-ceramic Denzir (DZ) and the glass-infiltrated In-Ceram Zirconia (InZ). All reconstructions were functioning properly at the 5-year follow-up visit; however, superficial veneer fractures were observed in nine out of 13 DZ restorations and in two out of 12 InZ restorations. In a prospective study [19], 10 patients received mandibular full-arch zirconia-ceramic (Cercon technique) FDPs. After 3 years, all restorations were in use. However, superficial veneer fractures were observed in nine patients (34 of 99 units). In a retrospective study [4], 26 zirconia-ceramic and 140 metal-ceramic FDPs supported either by implants (n = 118) or a combination of tooth and implants (n = 48) showed three (1.8%) failures (reasons: two implant failures and one extended chipping of the veneer). There were a total of 29 (17%) chippings after a median observation period of 14 months. Chipping occurred earlier in zirconia-ceramic FDPs than in metal-ceramic FDPs, but the overall difference was statistically not significant.

This small number of studies could have two reasons: First, the majority of zirconia-based systems have only been available for clinical use since the late 1990s. Second, all-ceramic restorations were commonly cemented to abutments by permanent cements or adhesive resins [7,12,18,19]. This practice may interfere with the retrievability to manage complications without damaging the fixed prostheses [6–8,20]. The aim of this study was to test the hypothesis that retrievable, tooth-implant supported FDPs made of veneered zirconia ceramic cores are viable treatment alternatives.

Material and methods

Patients and restorations

This study was comprised of a retrospective assessment of patient records and a clinical follow-up examination of all partially edentulous patients with tooth-implant supported FDPs made of veneered zirconia ceramics between July 2004 and August 2007. Further inclusion criteria were: presence of antagonistic teeth or implants, abutment height >4 mm for a sufficient connector area, free of periodontal disease (probing depth ≤4 mm, no bleeding on probing) and vital or endodontically-treated teeth with a sealed root filling to the apical region without apical periodontitis. Patients reporting bruxism or exhibiting the corresponding signs, such as advanced tooth wear, were also included because these individuals belonged to the clientele of an average general dental practice. The patients were recruited in a private practice or a dental clinic in Germany. This study was approved by the Ethics Committee of the University (BB 61/09) and all participants gave informed written consent. The study conformed to the principles embodied in the Helsinki Declaration of 1975, as revised in 1983.

The inclusion criteria fit 23 patients (12 females and 11 males). Two patients with tooth-implant supported all-ceramic restorations in the mandible were excluded because one opposite maxilla showed a shortened dental arch and the other a complete denture. In the private practice setting, 15 patients received 34 implants (Tiolox implants, Tiolox Implants GmbH, Dentaurum Company, Ispringen, Germany) and restorations that were performed by one dentist between March 2003 and November 2006. In the dental clinic, the implants of eight patients (four Tiolox implants; eight Ankylos implants, Friadent GmbH, Mannheim, Germany; five Straumann implants, Institute Straumann AG, Basel, Switzerland) were inserted by one surgeon and restored by another dentist between May 2005 and July 2007. The healing periods between implant placement and prosthodontic treatment were ~ 6 months in the

Table I. Description of patients, fixed dental prostheses (FDPs) and technical complications.

Patient No.	FDP No.	Practice or clinic	Gender	Abutments/pontics*	Self-reported bruxism	Severe tooth wear	First event	Event (month)	Still *in situ* (month)
1	1	Practice	Man	34t-35p-36p-37i			0		30.3
1	2	Practice	Man	47i-46p-45t-44t			Minor chipping 46	0	30.3
2	3	Practice	Woman	46i-45p-44t			0		45.0
3	4	Practice	Woman	47i-46p-45t			0		33.3
4	5	Practice	Man	11i-21p-22t			0		24.6
5	6	Practice	Man	34t-35t-36p-37i		X	Minor chipping 35	37.1	37.1
6	7	Practice	Woman	46p-45i-44p-43t-42i-41p-31p-32p-33i-34i-35i-36p			0		26.7
7	8	Practice	Woman	13i-12t-11i-21i-22t-23t			0		42.1
8	9	Practice	Woman	34t-35p-36i			0		37.3
8	10	Practice	Woman	46i-45p-44t			0		37.3
9	11	Practice	Woman	34t-35p-36i			0		37.3
10	12	Practice	Man	35t-36i-37i			0		47.9
10	13	Practice	Man	44t-43p-42i-41p-31p-32p-33t-34t			0		47.9
10	14	Practice	Man	45i-46i-47t			0		47.9
11	15	Clinic	Woman	22p-23t-24p-25p-26i-27i		X	0		25.1
12	16	Clinic	Woman	16i-15i-14p-13p-12t			0		25.9
13	17	Clinic	Woman	16i-15p-14i-13p-12t		X	Minor chipping 16	2.4	32.4
14	18	Clinic	Man	23i-24t-25p-26i-27t			0		13.2
15	19	Clinic	Man	34t-35i-36i			0		12.7
16	20	Clinic	Man	11t-12p-13t-14p-15i-16i		X	Core fracture 13	4.8	no
17	21	Clinic	Woman	33i-34p-35t-36i-37i	X	X	Core fracture 36	8.4	no
18	22	Clinic	Man	34t-35p-36i	X	X	Minor chipping 36	24.9	24.9
18	23	Clinic	Man	44t-45p-46i	X	X	Minor chipping 36	24.9	24.9
19	24	Practice	Man	15t-16i-17i			0		25.6
20	25	Practice	Woman	23i-24p-25i-26t-27t	X		Minor chipping 26	13.6	24.4
21	26	Practice	Woman	14t-15p-16i		X	0		20.7
21	27	Practice	Woman	45t-46p-47i		X	Minor chipping 45	1.0	20.7
22	28	Practice	Man	34t-35p-36p-37i		X	Minor chipping 37	0.8	20.2
22	29	Practice	Man	33t-32p-31i-41p-42i		X	Minor chipping 32	0.8	20.2
22	30	Practice	Man	43i-44p-45p-46i-47p-48t		X	Minor chipping 46	0.8	20.2
23	31	Practice	Man	44t-45p-46i			0		27.6

*Federation Dentaire Internationale (FDI) tooth numbering system; i, implants; t, teeth; p, pontics.

maxilla, 3 months in the mandible and 6 months after augmentations. The age of patients at the time of prosthesis insertion ranged from 41.1–69.8 years (mean: 56.8 years). The details of the FDPs are shown in Table I. From a total of 91 abutments, 40 were teeth and 51 were implants. Out of the 23 patients, four patients received two FDPs, two patients received three FDPs and the remaining 17 patients each received a single FDP. There were 15 3-unit, four 4-unit, six 5-unit, four 6-unit, an 8-unit and a 12-unit restoration. Only two FDPs had cantilevers.

Prosthodontic procedure

The teeth were prepared with a deep chamfer (≥0.8 mm), occlusal reduction of 1.5–2 mm, a convergence angle of ~ 10–15° and rounded inner and outer angles. After taking impressions of the teeth and implants, the models were cast using type IV dental stone (Esthetic-base 300, Dentona AG, Dortmund, Germany). Implant abutments were made of titanium alloy and were prepared for length and parallelism. For the abutment teeth, protective copings were designed and milled using CAD/CAM technology

Figure 1. Coping milled of pure titanium on a first premolar in the mandible.

(Everest system, KaVo, Biberach, Germany). The copings for 15 FDPs were composed of pure titanium with a wall thickness of 0.1–0.2 mm (Figure 1). The copings of 16 FDPs were milled from pre-sintered, yttrium-stabilized zirconia blanks with a wall thickness of ~ 0.4 mm. The chalk-like frames were coloured when needed and subsequently dense-sintered. In this fully sintered stage the zirconia frames can be manually re-milled up to a minimal wall thickness of 0.25 mm at the margins (Figure 2).

After a second scan of the model with the copings in place, the framework was anatomically designed with a connector diameter of at least 3.5 mm [21]. The FDP cores were also milled from pre-sintered zirconia ceramic blanks (Figure 3) and veneered using Esprident Triceram (Dentaurum- Company, Ispringen, Germany). The protective copings were permanently cemented with either zinc phosphate cement (Harvard Cement, Harvard Dental GmbH, Berlin, Germany) or glass-ionomer cement (Fuji I, GC, Tokyo, Japan) in the private practice, while dual-activated composite cement (Panavia F2.0, Kuraray Medical Inc., Japan) was used in the university clinic (Figure 4). Occlusal contacts of the FDPs were evaluated with articulating ribbon, adjusted using fine-grit diamond burs with water spray if necessary, and then polished. Semi-permanent acrylic-urethane cement (IMProv, Alvelogro Inc., Union, WA/USA) was used to fix the FDPs onto the protective copings and the implant abutments (Figure 5). Prior to cementing, the internal surfaces of the secondary crowns were isolated with a very thin layer of petroleum jelly, according to the instructions of the cement manufacturer. Patients were informed about the risk of restoration loosening. Regular follow-up appointments were scheduled at 3 months post-surgery and twice a year thereafter.

Data assessment

Data on surgical, restorative and prosthetic complications were assessed from the patient records. Surgical complications were defined as any evidence of peri-implantitis, implant loss or tooth loss. Endodontic treatment and caries were specified as restorative complications. Prosthetic complications were defined as screw and abutment loosening, screw or abutment fracture, retention loss of coping or FDP, coping or core fracture, fracture of porcelain veneers, intrusion of abutment teeth and replacement of restorations.

Between January and July 2009, a trained clinician who was not involved in the treatment of the patients performed the final clinical examination. The gingival and peri-implant conditions were recorded at abutments by gently moving a blunt periodontal probe in the marginal part of the sulcus. Bleeding was recorded as present or not. The restorations were inspected using a dental mirror and a dental probe for framework fractures, fractures of veneering material (minor/major chipping), loss of retention and caries at the abutment teeth. According to Kinsel and Lin [22], fractures of the veneering material were classified as minor chippings (defective surface that can be polished) or major chippings (surface is fractured and restoration must be repaired or replaced). If no functional or esthetic limitations occurred, the patient could decide whether the veneer fracture should be

Figure 2. Coping milled of zirconia ceramic.

Figure 3. Framework for a five-unit FDP milled of zirconia ceramic.

Figure 4. Abutments for the tooth-implant supported FDP. A third implant in the canine position failed after 3 months and the patient did not wish any replacement (see Figures 2 and 3 for the coping and framework).

repaired or not. The margin integrity was examined according to a slightly modified version [18] of the California Dental Association's (CDA) system for qualitative assessment of dental care [23] as follows:

- Romeo : No visible evidence of crevice along the margins; no catch or penetration of the explorer;
- Sierra: Slight marginal discrepancy detectable, no penetration of the explorer;
- Tango: Visible evidence of crevice and penetration of the explorer; and
- Victor: Mobile, fractured or missing restoration.

The severity of occlusal wear for posterior teeth (premolars and molars) and for posterior restorations

Figure 5. FDP of Figures 2,3,4 attached with the acrylic-urethane cement.

(crowns and pontics) was recorded for each patient. Dental arches were classified according to the two most severely affected teeth/units of restoration using the following modified scoring system [24,25]:

- 0 = No wear facets on teeth and/or restorations;
- 1 = Slight wear facets into the enamel of the posterior teeth (wearing in cusp tips) and/or visible wear facets on restoration without alteration of the occlusal morphology;
- 2 = Moderate wear facets into the dentin of the posterior teeth (flattening of cusps and grooves) and/or moderate wear facets on restoration with slight alteration of the occlusal morphology; and
- 3 = Extensive wear into dentin with loss of crown height and/or extensive wear on restorations with severe alteration of occlusal contour.

Before treatment and during the follow-up examination the patients were surveyed on whether they or their partners were aware of daytime teeth clenching/grinding and/or nighttime grinding. Thus, signs of bruxism were defined as self-reported teeth grinding/clenching and/or occlusal wear of ≥degree 2, according to the aforementioned scoring. In addition, patients were interviewed on whether they were satisfied with the esthetic outcome and occlusal function (chewing ability) of their restoration (yes/no).

Statistical analysis

Descriptive statistics were used to evaluate the clinical outcome. Kaplan–Meier survival curves were used to depict failures and complications. Survival time was calculated from the cementation date to the date of the final follow-up visit or the date of the respective event. The relationship between five exposures (age, gender, bruxism, jaw and number of units) and the outcome (complication) over the observation period was analyzed using Cox regression. Robust confidence intervals were calculated to adjust for correlated observations within a subject using the corresponding option in STATA/SE software, version 10.1 (StataCorp LP, College Station, TX). Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated. A value of $p < 0.05$ was considered statistically significant.

Results

All 23 patients were followed for this evaluation (Table I). The follow-up period for patients, i.e. the time between the prosthetic placement and the final examination, ranged from 12.7–47.9 months (mean: 28.8 months ± 10.3 months). There were nine patients (13 restorations) with signs of bruxism (three reported on bruxism, eight had extensive wear of teeth and/or restorations). At the time of the final examination, bleeding after moving of the periodontal

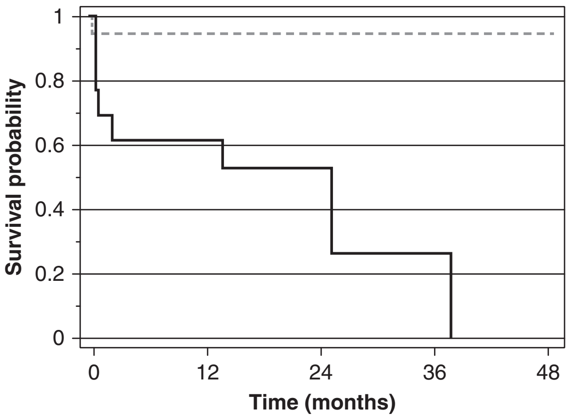

Figure 6. Kaplan-Meier curve for minor chipping of the veneering porcelain (broken line: signs of bruxism absent, solid line: signs of bruxism present).

probe in the sulcus was induced at three natural abutments and one implant. None of the abutment crowns were loosened and no caries were observed on the abutment teeth. The marginal adaption of the crowns was rated as Romeo (no visible evidence of crevise) or Sierra (no penetration of the explorer). All patients were satisfied with the esthetics and function of their restorations.

According to the patient records, core fractures occurred in the connector regions distally of the natural abutments within a maxillary 6-unit FDP and within a mandibular 5-unit FDP. Both patients (one man and one woman) of the dental clinic exhibited signs of bruxism and the female patient reported nighttime teeth grinding.

Figure 7. Occlusal veneer cohesive fracture at the distal implant after smoothing and polishing (same FDP as in Figures 2,3,4,5). Albeit the core shimmered through the porcelain the patient refused a repair.

There were 10 minor veneer fractures within the porcelain layer (cohesive chippings) of seven patients. Of these fractures, one chipping occurred in a 4-unit FDP (No. 2) during fitting. Three chippings were detected that the patients were not aware of before the final examination. The other chippings were observed between 0.8–37.1 months after service in two women and four men exhibiting signs of bruxism. The Kaplan-Meier analysis indicated that the overall chipping rate was 23% after 24 months and 39.2% after 40 months. The chipping rate at 40 months was 5.6% among patients without signs of bruxism and 100% among patients with signs of bruxism (Figure 6).

The chippings were primarily superficial and located on posterior teeth or implants, except for one anterior restoration. Upon request, the fractures were smoothed and polished (Figure 7). Loss of retention occurred on two posterior FDPs within a patient (No. 22) with veneering porcelain that had already been chipped on three restorations. The FDPs were re-cemented using acrylic-urethane cement. Abutment screw loosening occurred at the maxillary implant of patient No. 21. After non-destructive removal of the restoration, the screw was tightened and the FDP was cleaned and re-cemented. No other surgical, restorative or prosthetic complications were found during the observation period and the survival rate for the zirconia restorations was 93.5% after 40 months.

Only the exposure of interest and one additional variable could be simultaneously included in the Hazard model because the number of chippings was $\leq$10. The Cox regression analysis revealed a HR of 20 (95% CI = 2.1–188.3, $p = 0.009$) for signs of bruxism with a simultaneous inclusion of gender (HR = 0.6 for women, 95% CI = 0.2–2.0, $p = 0.392$).

Discussion

From 23 patients with 31 semi-permanently cemented restorations made of veneered zirconia-ceramic cores, 14 patients not reporting bruxism or not exhibiting advanced wear at posterior teeth and restorations showed no core fractures and only one chipping of the veneering porcelain. This minor veneer fracture was easy to treat because the restoration was damaged during fitting. However, among nine patients with signs of bruxism, two patients had core fractures of their restoration and six patients had chippings of the veneering porcelain after cementation.

Some aspects of this study merit further consideration. Both anterior and posterior restorations with span-lengths from 3–12 units and various distributions of natural and artificial abutments were considered. This diversity was due to the wide inclusion criteria for this retrospective study, regardless of location and extent of the restoration. Recent reports on the clinical performance of extended zirconia

FDPs confirmed that there has been an increase in the desire for multi-unit, all-ceramic FDPs [19,21].

In this study the copings were milled from pure titanium or zirconia. Initially, pure titanium was used to achieve a minimal wall thickness. Zirconia copings were later utilized more frequently as the esthetics at the crown margin is better compared to titanium. The influence of the coping material on the restoration bond strength should be an objective for any further investigations [10]. The private practice and dental clinic used different luting agents for the permanent cementation of the copings. This most likely did not have any clinical effect on the restorations because neither loss of cementations nor fractures of copings were observed. Straight and angled abutments of the three implant systems were achievable and had a deep chamfer. Thus, the fabrication of implant crowns with sufficient marginal and occlusal/incisal thickness was possible. Therefore, the utilization of different implant systems most likely did not affect the outcome.

Parafunction is difficult to quantify clinically [25,26]. In a sleep laboratory study, tooth wear at molars was determined to have the best capacity for predicting sleep bruxism and excluding a normal individual from a bruxism diagnosis [25]. Therefore, we chose the highest degrees of wear on at least two posterior teeth or restorations to increase the sensitivity of wear as bruxism sign.

Some restorations connected teeth and implants without the need for pontics (see Table I: restoration Nos. 8, 12, 14, 19, 24), this had the following reasons. First, the teeth with reduced periodontal support after periodontal treatment could be stabilized by implants (Nos. 8, 19) [2]. Second, the connections with teeth may prevent extra-axial loads on implants in cases of a significant distance between teeth and small-diameter implants that replaced molars (Nos. 12, 14, 24). Third, the respective crown may be easily reshaped into a pontic within retrievable multi-unit restorations if any abutment was lost.

Strength of this retrospective study was the independent examiner of the final follow-up who checked the restorations for location and size of chippings. Therefore, the reliability of patient record data was increased. None of the patients left the study during the evaluation period. Patients with parafunctional habits were not excluded to have a patient cohort that represented conditions of a general dental practice.

In most of the previous studies, examining all-ceramic restorations, temporary luting was not performed to avoid creating microcracks or flaws in the material during removal [13,18,19]. In the present study, all FDPs remained semi-permanently cemented to have the option for repair without destroying the prosthesis. There has only been one occasion of abutment loosening determined thus far. Therefore, there are no additional experiences on whether removal of all-ceramic FDPs cemented using the acrylic-urethane cement is possible without damaging ceramics or implant components.

The maximum retentive force that allows clinical retrievability is still unknown [6,10,20]. Previous results of *in vitro* studies suggest that conventional zinc oxide cements, instead of acrylic-urethane cement, are the first choice for temporary cementations of implant-supported restorations [9]. However, clinical studies of tooth-implant supported FDPs luted with zinc oxide cements exhibited multiple instances of spontaneous loosening and some intrusions of natural abutments [1]. In a previous study [11], the proportion of decementation of tooth-implant supported, metal-ceramic restorations luted with the acrylic-urethane cement was low compared to zinc oxide cements. Furthermore, attempts to remove the FDPs were always successful without any damage to dentures, abutment teeth, or implants. Comparisons with the present report are problematic, due to the low number of all-ceramic restorations and the shorter observation period.

In a systematic review, the annual technical complication rate for combined tooth-implant supported restorations with metal frameworks was 1.5% for fractures of veneer material, 1.5% for loss of retention, 1.4% for abutment/screw loosening, 1.1% for intrusions of abutment teeth and 0.33% for framework fractures [1]. In the present study, there were two framework fractures (6.5%), two losses of retention, one abutment screw loosening and no tooth intrusion. Fractures of the veneering porcelain were a frequent event (39.2% after 40 months). In studies on zirconia ceramic, core fractures do not seem to be a relevant problem for FDPs supported by posterior teeth [12–15] or implants [18,19]. However, these studies excluded patients with signs of bruxism. The most probable reason for the two core fractures was excessive occlusal contact because both fractures occurred in patients with severe tooth wear. Semi-permanent cementations might have contributed to increase the fracture risk. Albeit the two restoration loosenings were not associated with core fractures, the elastic properties of the acrylic-urethane cement may affect the fracture resistance of the zirconia-ceramic FDPs [7,10,20]. The fractured all-ceramic FDPs were replaced with metal-ceramic (titanium framework) restorations and cemented using acrylic-urethane cement. The CAD data for the zirconia cores were slightly modified for milling the titanium cores without the need for a new impression of the abutments. The all-ceramic copings were left unaltered *in situ.*

Chippings of the veneering ceramic were more frequent in this study than in many other studies evaluating zirconia restorations [13]. However, comparable to evaluations of implant-supported, zirconia-ceramic

FDPs, in which chippings occurred in nine out of 13 short-span FDPs after 5 year [18] and in nine of 10 full-arch FDPs after 3 years [19], the decreased tactile sensibility of implants (despite the teeth within our restorations) could be also assumed as one reason for multiple veneer fractures in this study.

In the present study, all veneer chippings after cementation occurred exclusively among patients with signs of bruxism at posterior parts of the restorations, except for one chipping of an anterior FDP. Similarly, in a study of implant-supported, metal-ceramic restorations, patients with bruxism had 7-fold higher odds of porcelain fractures than patients without bruxism [22]. Although patients with parafunctional habits were excluded in other evaluations of posterior zirconia FDPs supported by teeth, chipping seems to be a common problem [12–15]. A safe pre-treatment separation of patients with parafunctional habits from normal patients seems to be difficult [16,17]. The clinicians who placed the restorations have seen the advanced wear and were informed of the patient's bruxing habits from the patient history before treatment. Nonetheless, the treatment protocol was not changed for these patients. According to the present findings the use of veneered zirconia restorations for tooth–implant restorations should be avoided in patients with signs of bruxism.

Superficial cohesive fractures of the veneering porcelain were more frequent in other reports on zirconia restorations than adhesive fractures that expose the core [12–14,16,17], which corroborate the results of the present study. The patients with minor chippings did not want any repair and the restorations remained *in situ* similar to other studies [12–19]. The importance of minor chippings is low from the patient's point of view. All patients were still satisfied with their prostheses. From the clinical view, the chip-off fractures did rarely cause functional limitations of the restorations. Problems because of minor chippings only arise if the dental esthetics is compromised [16–19].

Within the limitations of this short-term study, tooth-implant supported FDPs comprised of veneered zirconia ceramic were determined to be used with caution because of some core fractures and a considerable number of minor veneer fractures. The fracture risk was very high among patients with signs of bruxism. The ability to use semi-permanent cements for zirconia restorations as tooth-implant supported FDPs remains unevaluated due to the low number of occasions for intentional retrievals. A recommendation of this cementing procedure would still be premature.

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