Survival and Chipping of Zirconia-Based and Metal–Ceramic Implant-Supported Single Crowns

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ABSTRACT

Purpose: The objective of this retrospective study was to compare the incidence of chipping of implant-supported, all-ceramic, and metal–ceramic single crowns.

Material and Methods: One hundred fifty-three patients (51.7% male, mean age 55.0 years) received 232 cemented implant-supported single crowns. One hundred and seventy-nine crowns had a metal framework (gold alloy) and 53 crowns were all-ceramic (zirconia framework and glass–ceramic veneer material). Age, gender, kind of cementation, and location of the restorations were assessed as possible factors affecting chipping.

Results: During the observation period of up to 5.8 years (mean 2.1 years; standard deviation 1.4), a total of 13 (24.5%) all-ceramic and 17 (9.5%) metal–ceramic crowns suffered from chipping, a difference that was statistically significant. A total of ten single crowns had to be remade resulting in survival of 86.8% (all-ceramic) and 98.3% (metal–ceramic). The other possible factors did not have a significant effect on the chipping.

Conclusion: Chipping was found to be more frequent for all-ceramic implant-supported single crowns. If the reasons for the vulnerability of all-ceramic crowns remain unknown, implants with all-ceramic single crowns should generally be recommended with care.

KEY WORDS: all-ceramic, chipping, implants, metal–ceramic, single crowns, survival

INTRODUCTION

Therapy for missing single teeth has become frequent and important in modern dentistry. Therapeutic options for replacement of a single missing tooth include resin-bonded fixed partial dentures, either all-ceramic[1] or based on a nonprecious cobalt chromium (CoCr) alloy,[2] conventional fixed partial dentures,[3–5] and implant-supported single crowns.[6–8] Metal–ceramic single crowns have been made for decades and are regarded as the gold standard, both on teeth and implants.[9–11] In recent years, all-ceramic single crowns have become more popular.[12–14] However, the lower fracture toughness, bending strength, and splitting tensile strength of the early materials allowed usage, especially in posterior regions, to a limited extend only.[15] The introduction of zirconia-based all-ceramic with high-fracture resistance has encouraged the use for highly loaded restorations, in particular, in the molar region.[16]

In recent years several clinical trials[17] and reviews have been published on implant-retained single crowns. Jung and colleagues, in a systematic review of 26 studies with a total of 1,558 implants, evaluated survival and incidence of complications for implant-supported single crowns.[18] Meta-analysis of these studies revealed 5-year implant-survival of 96.8%. Five-year survival of implant-supported single crowns was 94.5%, and that of metal–ceramic crowns was significantly higher than that of all-ceramic crowns ($p = .005$). Strub and colleagues, in a review of 15 short-term and 17 long-term studies,

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examined prosthetic outcome for cemented, implant-supported fixed restorations.[19] These studies gave no information or guidelines about the cement or cementation procedures used for cement-retained restorations on implants.

Patients with just one missing tooth are particularly interested in long-lasting, minimally invasive therapy, not least to save the substance of neighboring teeth. Beside the decision about therapy, the materials chosen and the associated aftercare are major concerns both for the patient and for the dentist, who, in cases with complications, have to accept the amount of chair time required. Only few studies have yet reported on all-ceramic, implant-supported single crowns.

The objective of this retrospective study was, therefore, to assess the incidence of chipping of implant-supported cemented single crowns fabricated at the Department of Prosthodontics in the years 2002 to 2010. All-ceramic crowns and single crowns with a metal framework were examined.

The null-hypothesis was that there is no difference between the incidence of chipping of all-ceramic implant-supported single crowns and crowns with a metal framework.

MATERIALS AND METHODS

Patients consulting the Department of Prosthodontics, University of Heidelberg, who were in need of oral prosthetic rehabilitation, including single implant placement, and who fulfilled the inclusion criteria were enrolled in this study. The study was a retrospective analysis of prospectively documented material. Data were extracted with the aid of a data-extraction sheet. The prospective study, documenting all implants and suprastructures inserted and fabricated at the Department of Prosthodontics, Heidelberg, was approved by the regional ethics committee (27/2005). Patients received detailed information about the procedures used and were required to sign an informed consent form before participation.

The inclusion criteria for this analysis were presence of a single tooth gap to be restored by implant insertion, receiving both implant and suprastructure from the Department of Prosthodontics, Heidelberg, between June 2002 and January 2010, and signing the informed consent form for documentation.

A total of 153 patients (51.7% male, mean age 55.0 years at the time of implant insertion, standard deviation [SD] 13.2) received 232 cemented single crowns on 232 implants. All implants were placed in accordance with the standard procedures recommended by the manufacturers. One hundred twelve implants were inserted in the maxilla, 24 in the anterior region, and 88 in the posterior region. One hundred twenty implants were placed in the mandible, two in the anterior region and 118 in the posterior region. Three different types of implant were used: type A, with 175 implants (Straumann Tissue Level® implants, Straumann GmbH, Basel, Switzerland), type B, with 49 implants (Nobel Replace®, Nobel Biocare, Göteborg, Sweden), and type C, with 8 implants (Straumann Bonelevel®, Straumann GmbH).

The observation period of the implants started at implant placement. After a healing period of 3–9 months the fixed dentures were fabricated and incorporated. A total of 232 implant-retained single crowns were placed. One hundred seventy-nine crowns had a gold-alloy framework faced with glass–ceramic (Duceram® Kiss, DeguDent GmbH, Hanau, Germany; VITA VM13®, VITA Zahnfabrik, Bad Säckingen, Germany; Reflex®, Wieland Dental GmbH, Pforzheim, Germany); the other 53 crowns were all-ceramic – a zirconia framework (Cercon®, DeguDent GmbH; Zenotec®, Wieland Dental GmbH) with glass–ceramic veneer (Cercon® Ceram Kiss, DeguDent GmbH; Zirox®, Wieland Dental GmbH). The frameworks were anatomically shaped to ensure the support of the veneer material. All crowns were cemented; the material used was chosen by the dentist. According to the manufacturers' data, semipermanent cements (Dycal®, DENTSPLY DeTrey GmbH, Konstanz, Germany; TempBondT, Multident Dental GmbH, Hanover, Germany) and permanent cements (Harvard®, Harvard Dental International GmbH, Hoppegarten, Germany; KetacT Cem, 3M ESPE GmbH, Neuss, Germany; RelyXT Unicem, ESPE GmbH, Germany) were suitable. Semipermanent cements were used to fix 54.7% of the crowns; the other 45.3% were fixed by permanent cementation.

Every dentist had to maintain baseline documentation including prosthetic procedure, fixing procedure, and the material of the single crowns. Patients were recalled after 6 months, 12 months, and then at 1-year intervals. In addition to the recall intervals, the patients were requested to consult the clinic immediately after recognition of any complication. It was, therefore, possible to record the real failure time. In this clinical trial,

any intervention for single crowns was counted as a complication. Occurrence of complications and the measures implemented were documented separately on standardized complication forms. Depending on the extent of the complication, the single crowns were repaired chair-side or at the dental laboratory. If repair was not possible the single crown was remade.

All data were analyzed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). With any occurrence of chipping regarded as an event, Kaplan–Meier survival curves were plotted for the groups all-ceramic crowns and metal–ceramic crowns. Differences between successes were estimated by use of log-rank tests. Because a patient could have received more than one crown and events may not have been independent of the factor "patient", a non-time dependent general estimation equation model (GEE; binary logistic, chipping yes/no as target variable) was produced with age, gender, material of the suprastructure (all-ceramic/metal–ceramic), cementation type (semipermanent/permanent), occurrence of de-cementation (yes/no), and location of the restoration (anterior/posterior) as independent factors/covariates to support the results of the log-rank test. The probability level for statistical significance was set at alpha < 0.05.

RESULTS

During the implant observation period of up to 6.19 years (mean 2.80 years; SD 1.35), one implant with clinical signs of peri-implantitis was lost after 3.04 years in service resulting in an implant survival rate of 99.6% (Figure 1). The observation period of the implants started at implant placement.

During the single crown observation period of up to 5.8 years (mean 2.1 years; SD 1.4) 177 implant-supported single crowns (76.3%) were free from technical complications. The most common complication, fracture of the veneer material, occurred on 30 single crowns (see below). Loss of retention occurred for 27 single crowns when 23 metal–ceramic crowns were affected. Seventeen of these crowns were fixed with semipermanent cement. Another metal-ceramic crown was lost because the patient had swallowed it after fracture of the luting cement. The cumulative survival was 86.8% for all-ceramic and 98.3% for metal–ceramic single crowns (Figure 2). Abutment screw loosening was not observed and no crown fractured. Therefore, the success achieved, counting every measure implemented as a complication, was 80.8% after 2 years of observation and 69.8% after up to 4.4 years for all-ceramic crowns, respectively, 95.8% after 2 years and 78.2% after up to 5.8 years for metal–ceramic crowns (Figure 3).

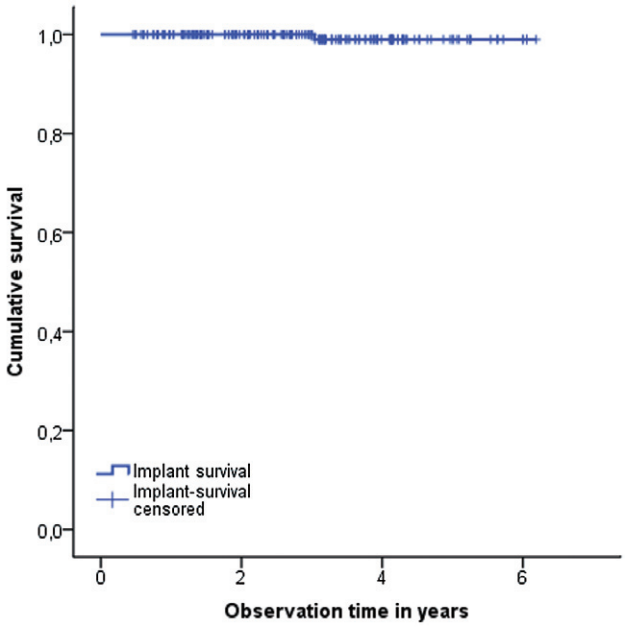

Figure 1 Kaplan–Meier survival curve for the implants starting at implant placement.

Descriptions for possible factors affecting the incidence of chipping, stratified for the groups "crowns with/without chipping" and the total number of crowns,

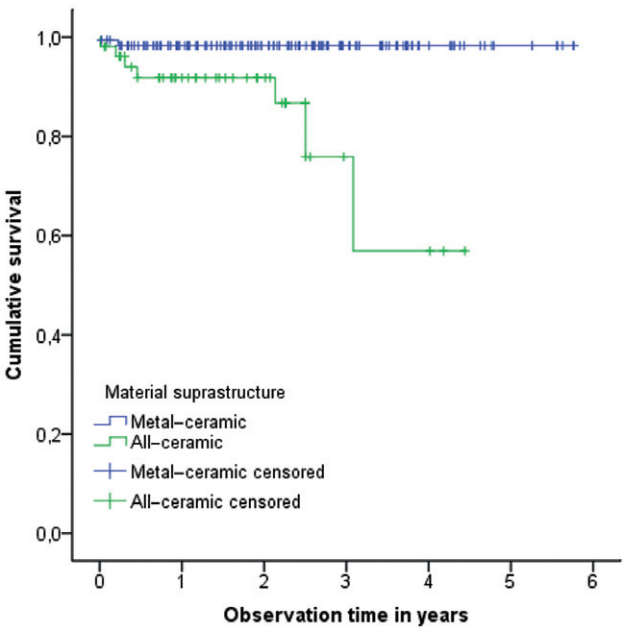

Figure 2 Kaplan–Meier survival curves for all-ceramic and metal-ceramic single crowns.

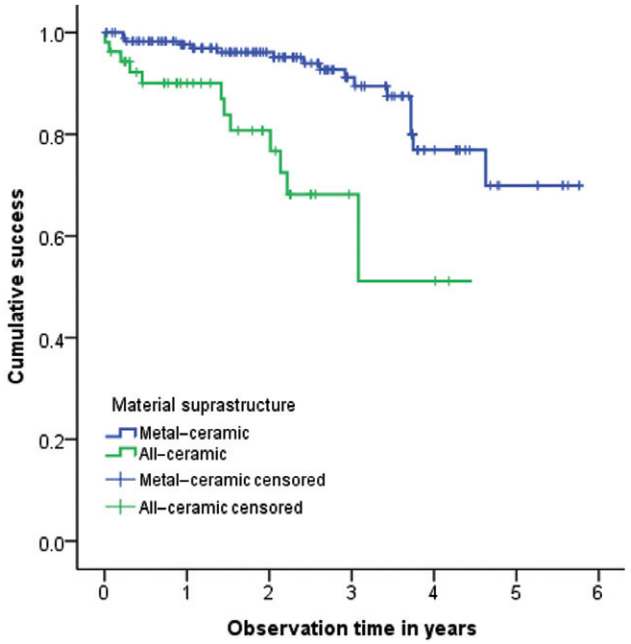

Figure 3 Kaplan–Meier curves for chipping of all-ceramic and metal-ceramic single crowns.

are listed in Table 1. All-ceramic crowns were affected significantly more often over time than crowns with a metal framework (log-rank $p < .001$, Figure 3). The GEE model estimated not time-dependent risk of chipping to be 3.8 times higher in the all-ceramic group than in the metal–ceramic group (lower bound of 95% confidence interval [CI] 1.7; $p = .001$; Table 2). Eight single crowns had to be remade because of major chipping of the veneer; of these, six were all-ceramic and two were metal–ceramic. Other factors (i.e., location, luting cement, age, gender, and occurrence of de-cementation) had no statistically significant effect on the incidence of chipping.

DISCUSSION

The null-hypothesis of this study, that there is no difference between the incidence of chipping of all-ceramic and metal–ceramic implant-supported single crowns, could not be confirmed. Rather, the incidence of chipping for all-ceramic crowns was significantly greater than that for metal–ceramic crowns ($p = .001$) with a 3.8 times greater risk of chipping (lower bound 95%-CI 1.7).

The results of this analysis are in accord with the literature. Though comparability is limited because of the several all-ceramic systems examined. In a review, Jung and colleagues[18] found that survival of all-ceramic crowns (91.2%) was significantly inferior to that of crowns fabricated with a metal framework (95.4%). The results are also confirmed in a review by Salinas and Eckert, who found that survival of single crown restorations documented in 13 studies was 94.5% and was significantly higher for metal–ceramic crowns (95.4%) than for all-ceramic crowns (91.2%).[20] In another review, Pjetursson and colleagues compared the survival of several all-ceramic single crowns with that of metal–ceramic crowns and described the incidence of biological and technical complications.[21] Five-year survival of all-ceramic crowns was estimated to be 93.3% whereas it was 95.6% for metal–ceramic crowns. Five-year survival was highest for densely sintered alumina crowns, followed by reinforced glass-ceramic and InCeram® crowns. Survival of glass–ceramic crowns was significantly lower after this observation period. Survival of all four types of all-ceramic crown was lower when seated on posterior teeth. In this study of all-ceramic crowns made with zirconia and gold-alloy frameworks, the incidence of complications was also highest for single crowns in the posterior mandible although the effect was not statistically significant ($p = .115$).

TABLE 1 Descriptives of Factors Possibly Affecting the Incidence of Chipping, Stratified for the Group "Crowns with/without Chipping" and the Total Group

	Occurrence of Chipping		
Factor	No	Yes	Total Group
Age* (mean/SD)	55.3 years (SD 12.8)	53.0 years (SD 15.9)	55.0 (SD 13.2)
Gender*			
Male	104 (44.8%)	16 (6.9%)	120 (51.7%)
Female	98 (42.2%)	14 (6.0%)	112 (48.3%)
Material			
Metal–ceramic	162 (90.5%)	17 (9.5%)	179 (77.2%)
All-ceramic	40 (75.5%)	13 (24.5%)	53 (22.8%)
Luting cement			
Semipermanent	112 (48.3%)	15 (6.5%)	127 (54.7%)
Permanent	90 (38.8%)	15 (6.5%)	105 (45.3%)
Loss of retention			
No	178 (76.7%)	27 (11.6%)	205 (88.4%)
Yes	24 (10.3%)	3 (1.3%)	27 (11.6%)
Location			
Anterior	25 (10.8%)	1 (0.4%)	26 (11.2%)
Posterior	177 (76.3%)	29 (12.5%)	206 (88.8%)

*One patient could have received more than one crown. SD = standard deviation.

TABLE 2 General Estimation Equation Model for the Dependent Variable "Occurrence of Chipping"

Factor	Exp (B)	Significance	95% Wald Confidence Interval	
			Minimum	Maximum
Age	1.011	0.519	0.978	1.046
Gender				
Male	0.795	0.601	0.337	1.875
Female	1	—	—	—
Material				
Metal—ceramic	3.807	0.001	1.669	8.683
All-ceramic	1	—	—	—
Luting cement				
Semipermanent	0.774	0.534	0.345	1.737
Permanent	1	—	—	—
Loss of retention				
No	0.874	0.841	0.236	3.236
Yes	1	—	—	—
Location				
Anterior	6.283	0.115	0.638	61.858
Posterior	1	—	—	—

Muche and colleagues in a prospective long-term study examined 46 implant-supported single crowns and estimated success to be 86.4% after a 3-year observation period.[22] Polishing of the veneer material, minimum correction of occlusion, and screw loosening up to once a year were counted as success. With success of 80.8% after 2 years and 69.8% after up to 4.4 years for all-ceramic, respectively 95.8% after 2 years and 78.2% after up to 5.8 years for metal–ceramic, the results of our study are inferior to those described above. In this study, only suprastructures without any intervention were counted as successful. Our results are more comparable with those in the study of Brägger and colleagues, who examined a total of 69 implant-supported single crowns of 48 patients in a prospective cohort study.[23] During the observation period of 10 years, 46 (66.5%) single crowns resulted in no complication. The authors also recommended use of definitive cementation to avoid complications; during the whole observation period, loss of retention occurred in two cases without any further consequences. After chipping of the veneer material, fracture of the luting cement was the second most common complication occurring for the single crowns in our study. Loss of retention occurred for 27 single crowns. However, neither the luting cement used nor the occurrence of de-cementation had any statistically significant effect on the frequency of chipping of the veneer material ($p = .115$; $p = .841$). The other possible factors age ($p = .519$) and gender ($p = .601$), also had no significant effect on the incidence of chipping. The results of this study are based on retrospective analysis of documentation forms and patient charts. The choice of material for the crowns depended on the treating dentist and on the patients' wishes only. This resulted in different sample sizes in the two groups. Thus, all dentists treated the same kind of subject. Obviously, this does not guarantee generalizability, but it seems to be adequate for assessment of the incidence of chipping of all-ceramic crowns compared with metal–ceramic crowns in this specific study setting.

On researching the literature, several factors are found to be associated with chipping of all-ceramic crowns: the thickness of the veneer material and its mechanical properties; the direction, frequency, and magnitude of the applied load; residual stress in the veneer material[24]; the presence of internal defects and damage; and the strength of the veneer material must all be considered.[25] Fischer and colleagues examined the effect of thermal misfit on the shear strength of 12 different ceramic–zirconia composite veneer materials.[26] For 11 specimens fracture started at the core–veneer interface and proceeded into the veneer ceramic

(observed under a scanning electron microscope after debonding). The authors concluded that thermal expansion and the glass transition temperature of the ceramic veneer material affect the shear strength of veneer–zirconia composites. Ashkanani and colleagues compared the in vitro strength of zirconia with that of the corresponding porcelains, and as a result recommended improving the strength of veneering ceramics to reduce the likelihood of chipping of porcelain veneer.[27] Land and Hopp in a review examined survival rates of several all-ceramic systems on teeth depending on clinical indication and fabrication method.[28] They suggest that many all-ceramic restorations were found to demonstrate acceptable longevity. Nevertheless, although zirconium systems offer the advantage of favorable material characteristics for substructures, the authors found that the clinical problem of chipping of the weaker esthetic veneer persists.

The causes of the higher incidence of chipping of all-ceramic crowns have not yet been completely investigated, however, and further prospective and randomized clinical studies are needed.

CONCLUSION

Survival and success of implant-supported all-ceramic single crowns with zirconia frameworks are significantly inferior to those of metal–ceramic crowns. Chipping was more frequent and resulted in greater need for renewal of all-ceramic implant-supported single crowns than of the metal-based crowns. For as long as the reasons for the greater incidence of chipping remain unknown, general recommendation of all-ceramic single crowns on implants should be made with care.

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CONFLICT OF INTEREST AND SOURCE OF FUNDING STATEMENT

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