Occlusal Wear of Metal-Free Ceramic-Filled Polymer Crowns After 2 Years in Service

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Purpose: Improvements in the physical properties of modern composites have led to continuous expansion of their field of application to include extensive, occlusion-bearing posterior restorations and even metal-free polymer crowns. The objective of this clinical study was to investigate the influence of gender, arch, and crown location on the occlusal wear of metal-free ceramic-filled polymer crowns and to compare their wear with the mean annual occlusal wear of enamel (15 to 38 µm). ***Materials and Methods:*** One hundred fourteen ceramic-filled polymer crowns made of Artglass (Heraeus Kulzer) were placed in 74 patients. After 1 year, 93 crowns were available for wear measurement. After 2 years, 76 crowns were available. Wear was determined by use of replicas. A 3-dimensional optical profilometer (Laserscan 3D, Willytec) was used to digitize and superimpose the occlusal surfaces of the baseline and recall replicas (occlusal matching). ***Results:*** After 1 year, median wear of the entire occlusal surface was 19 µm for anterior and canine teeth, 19 µm for premolars, and 21 µm for molars. After 2 years, median wear was 36 µm for anterior and canine teeth, 44 µm for premolars, and 84 µm for molars. The wear of the occlusal contact areas was significantly higher. Significant effects of crown location (premolar or molar) on the extent of wear of the occlusal contact areas were found. ***Conclusions:*** Ceramic-filled polymer crowns are subject to measurable occlusal wear that exceeds that of natural enamel. *Int J Prosthodont 2008;21:161–165.*

Dental clinicians can choose from a large variety of materials and techniques for crown restoration of heavily decayed teeth. Metal-ceramic crowns have proved their worth over decades of use for restoring destroyed teeth or retaining fixed prostheses.[1–3] However, problems related to metal-ceramic crowns have become evident, such as impaired esthetics caused by the metal framework, especially at the crown margins. Thus, ceramic materials without metal reinforcement have been developed to fabricate crowns. Clinically proven and highly esthetic all-ceramic crown systems are now available. Clinical studies have proved that survival of these high-strength all-ceramic crowns is comparable with that of metal-ceramic crowns.[4–6]

One inexpensive option is metal-free crowns made of ceramic-filled polymers, such as Artglass (Heraeus Kulzer). For a long time, crowns based on polymethyl methacrylate (plastic jacket crowns) have been used as provisional restorations only, if at all, because of the disadvantages of this material, such as the tendency to become discolored, increased plaque formation, and insufficient wear resistance. It was not until the development of composite materials with an organic matrix containing inorganic filler particles (eg, powdered glasses or ceramics) that substantial improvements in the material properties of polymeric materials were achieved. Today, composites are successfully used as filling materials for a wide range of applications and as veneers for removable anchoring devices such as telescopic crowns.[7,8] Because Artglass showed favorable physical properties and satisfactory fracture resistance in 2 in vitro studies,[9,10] researchers conducted clinical tests on ceramic-filled polymer crowns.[11–14] It was

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found that after 2 years in service, Artglass crowns were often susceptible to decementation (because of an inappropriate luting method) and surface degradations and wear in the occlusal contact area.[11] Rammelsberg et al[14] reported a 3-year survival rate of 96% with good functional and esthetic results for Artglass crowns on anterior and posterior teeth. The clinical survival of glass fiber–reinforced ceramic-filled polymer crowns made from Targis/Vectris (Ivoclar Vivadent) was not as good.[12,13] Another clinical investigation proved the biocompatibility and good local tissue compatibility of Artglass and Targis/Vectris.[15]

If the occlusal surface includes intact enamel areas, the clinical wear of extensive, occlusion-bearing direct composite restorations is now regarded as unproblematic.[8,16] However, the clinical wear behavior of ceramic-filled polymer crowns used for restoration of complete occlusal surfaces and the question of whether these materials enable lasting reconstruction of a stable occlusion have not been systematically examined. According to in vitro studies, the wear resistance of modern composites is acceptable but not as good as that of reference materials such as amalgam or gold alloys.[9,17–21] Two clinical investigations reported occlusal wear of ceramic-filled polymer crowns, but did not quantify this wear[12] or comprehensibly describing the test method.[11] Thus, the objective of this prospective study was to evaluate the wear behavior of metal-free ceramic-filled polymer crowns; to investigate the influence of gender, jaw, and crown location on the occlusal wear; and to compare the annual mean occlusal wear with that of enamel (15 to 38 μm).[22]

Materials and Methods

The study procedure was checked and approved by the local ethics committee. A total of 114 ceramic-filled polymer crowns made of Artglass in 74 patients aged 20 to 81 years (median: 50.5 years, 66% women) were included in the study. The inclusion criteria were patients who needed a single tooth restored with a crown and who provided written consent. After 1 year, 93 crowns were available for wear measurement. After 2 years, 76 were available (dropout rate: 18.4% after 1 year and 33.3% after 2 years). The most common reasons for dropout were faulty impressions or replicas that were unsuitable for wear testing, and that some patients did not wish to participate in a recall or moved away.

Six experienced clinicians performed the preparation and placement. The clinicians were required to perform standardized preparations (0.5-mm shoulder or 0.5-mm chamfer) with an occlusal reduction of at least 1.0 mm. A polyether material (Impregum, 3M ESPE) was used to make impressions. The Artglass crowns were fabricated in a dental laboratory with the aid of unsectioned casts made of type IV stone (Kerr) in accordance with the manufacturer's recommendations. The fabrication process has been described in detail elsewhere.[10] After try-in and necessary occlusal corrections, the instrumented surfaces were polished using the Artglass toolkit (Heraeus Kulzer). This set of instruments, consisting of a variety of cross-cut carbide burs, a silicone polisher, and 3 polishing brushes used with polishing paste, ensured the surface quality of the ceramic-filled polymer crowns was the highest possible. The crowns were placed using luting composite (2bond2, Heraeus Kulzer), following the adhesive technique.

To evaluate wear, impressions of each crown were made directly after placement, after 1 year, and after 2 years, using addition-curing silicone material (Aquasil, Dentsply DeTrey), and replicas were made using type IV dental stone (GC Fujirock EP Pearl White, GC). The occlusal contact points were intraorally marked with 12-μm Hanel occlusion foil (Coltène/Whaledent) and photographed directly after placement and during the 2 subsequent evaluations. Wear was determined using a 3-dimensional (3D) laser scanner following the method described by Mehl et al.[23] First, the occlusal surfaces of the replicas were digitized using a 3D optical profilometer (Laserscan 3D). The settings for this scanning process were adjusted by increasing the number of read-in light lines from 400 to 700. The data sets obtained in this way were then checked for surface changes or wear with surface-analysis software (Match 3D, version 1.6, Willytec). The extent of wear was calculated by superimposing the original data on those from the respective recall (occlusal matching). This method was used without reference points, as described by Mehl et al,[23] which made it possible to determine surface changes with an accuracy of 10 μm. The objective of this automated superimposition process was to match the surface points of the recall replica with those of the baseline replica as precisely as possible. The number of calculation steps executed until termination of the calculation process was preset to 20,000. The minimum number of image points used for matching was 800. To prevent surface changes as a result of wear or artifacts in the replicas (eg, voids in the stone) from impairing the superimposition process, a threshold value of –30 μm was defined. This means that all areas of the recall replica that differed from the baseline replica by more than 30 μm in the negative direction were not included in the matching process. Matching was accepted when the standard deviations between the image points of the 2 occlusal surfaces were less than 20 μm. The results of this matching process were difference images showing surface changes (wear zones) in red in a false color representation. These difference images enabled the operators to measure the wear of both the entire occlusal surface

Table 1 Wear (µm) of the Entire Occlusal Surfaces and Occlusal Contact Areas After 1 Year and 2 Years*

	1 year		2 years	
	Entire occlusal surface	Occlusal contact area	Entire occlusal surface	Occlusal contact area
Anterior teeth				
n	36	–	30	–
Mean wear (SD)	37 (54)	–	43 (39)	–
Median wear	19	–	36	–
Premolars				
n	27	26	20	20
Mean wear (SD)	48 (79)[a]	54 (62)[a,c]	62 (47)[d]	74 (56)[d,f]
Median wear	19	29	44	56
Molars				
n	30	30	26	26
Mean wear (SD)	72 (119)[b]	105 (140)[b,c]	97 (89)[e]	114 (102)[e,f]
Median wear	21	46	84	103

*Same superscript letter indicates statistically significant difference.

and individual, interactively selectable areas (eg, occlusal contact areas). For each crown examined, the entire surface involved in occlusion was evaluated, ie, the occlusal surfaces of the molars and premolars, the palatal surfaces of the maxillary anterior and canine teeth, and the incisal surfaces of the mandibular anterior teeth. The occlusal contact areas of the posterior crowns were evaluated separately using photographs with marked contact points.

Statistical Analysis

For statistical evaluation, the wear of the entire occlusal surface and the wear of the occlusal contact areas of each crown examined were determined after 1 and 2 years in service. The data were statistically analyzed with the aid of SAS 9.1 software (SAS Institute). To evaluate the effects of gender, arch (maxilla, mandible), and crown location (anterior teeth, premolar, molar) on the extent of wear, mixed regression models (SAS PROC MIXED) were used, with the patient being a "random effect" and gender, arch, and tooth being "fixed effects." The target value "difference in wear after 1 and 2 years" was also tested with mixed regression models, including one constant (intercept) as a "fixed effect." To determine whether the wear of the entire occlusal surfaces differed statistically from that of the occluding areas, mixed regression models were also fitted. For all statistical calculations, a *P* value of .05 was chosen as the level of significance. No adjustment was made for multiple testing.

Results

The mean and median wear of the entire occlusal surfaces and occlusal contact areas are summarized in Table 1. The striking feature is the large standard deviations, which resulted from substantial individual variations in the wear of the different crowns. This is why the medians, which have the advantage of being more robust with regard to outliers than arithmetic means, are also given. After 1 year, wear of the entire occlusal surface was found to be 19 µm for anterior teeth, 19 µm for premolars, and 21 µm for molars. When evaluating the occlusal contact areas in isolation, the wear was 29 µm for premolars and 46 µm for molars. After 2 years, wear of the entire occlusal surfaces increased to 36 µm for anterior and canine teeth, 44 µm for premolars, and 84 µm for molars. Again, greater wear was measured in the occlusal contact areas: 56 µm for premolars and 103 µm for molars. Wear of the entire occlusal surfaces differed significantly from that of the occlusal contact areas, after both 1 year ($P < .001$) and 2 years ($P = .016$). The differences between the first and the second examinations were statistically significant in terms of both wear of the entire occlusal surfaces ($P < .001$) and wear of the occlusal contact areas ($P = .01$). Statistically significant effects of gender and arch on the extent of wear could not be proved. Wear of the occlusal contact areas of the molar crowns was statistically significantly higher than that of the premolar crowns after 1 years ($P = .04$) and 2 years ($P = .03$).

Discussion

Natural teeth and dental restorations are subject to continuous physiologic wear. The wear of restorative materials should be as similar as possible to that of natural teeth to preserve occlusal stability and avoid any consequential problems.[16] Laboratory simulation of the complex wear processes occurring in the oral cavity is poor at best, and methods of simulating wear lead to substantially different results.[24] It has not been scientifically proved that any wear simulator furnishes values for wear that correlate with those obtained clinically.[24] For this reason, clinical data on wear behavior are particularly valuable, even if clinical wear measurements are methodologically difficult and require great effort. Objective quantitative procedures, rather than subjective evaluation scales, should be used in clinical wear tests.[25] Noncontact 3D wear measurement with a laser scanner, as used in this investigation, is currently regarded as the most accurate and effective technique for clinical analysis of wear.[26]

In this investigation, as in most studies of clinical wear, the difference between the distance (µm) along the z-axis for the recall and baseline replicas was used to indicate the extent of wear. The advantage of this method over measurement of volumetric wear is that wear can be evaluated irrespective of the size of the surface examined. This is particularly important when different types of teeth with larger or smaller occlusal surface areas must be compared. Because approximately 250,000 surface points were compared to evaluate 1 occlusal surface, a single maximum value cannot show the wear in a statistically representative way. This is why this study does not report maximum wear values but instead describes wear using mean and median values only. The wear of the entire occlusal surface of a crown comprises the wear of both the occlusal contact areas and the contact-free areas. The benefit is that loss of material caused by both attrition (in the sense of 2-body wear processes) and indirect, 3-body wear of the contact-free areas is taken into account. The wear of the occlusal contact areas also enables conclusions to be drawn about the loss of occlusal support or possible elongation of the antagonist teeth; therefore, it is considered to be more clinically relevant.

Because this method of measurement is characterized by very good reproducibility,[23] the large variations in wear must be attributed to individual patient effects (nutrition, parafunctions, antagonists, etc). Unfortunately, these effects were not recorded systematically. Methodologic inaccuracies in impression making or replica fabrication may also be causes of the large variations in the wear measured. Despite these large standard deviations, the effects of crown location on the extent of wear were demonstrated.

Published results from other investigations can be used to check the plausibility of the wear measured in this study. In a clinical study, substantial occlusal wear of ceramic-filled polymer crowns (Targis/Vectris) was mentioned but not quantified.[12] Another clinical study of Artglass crowns reported mean wear of the entire occlusal surface of 77 µm after 1 year and 125 µm after 2 years.[11] This wear was measured using a technique called "computerized occlusal mapping," which is not described in detail. Unfortunately, the investigators did not distinguish between crown locations. However, the mean wear of the entire occlusal surfaces of the molar crowns in the present study is comparable with these results.

Because results from other studies on the clinical wear behavior of ceramic-filled polymer crowns are not yet available, comparison with similar materials (eg, denture teeth made of plastic materials) may be helpful. In a study by Lindquist et al[27] of patients with complete dentures, the mean wear of occlusal contact areas of denture teeth made of a variety of polymers ranged from 77 µm (SD: 39) to 103 µm (SD: 57) after 12 months. These results are similar to the mean wear of the occlusal contact areas in the present study. It must be taken into account, however, that the masticatory forces of patients with complete dentures are certainly different from those of the patients in the present study. It would also be interesting to study the clinical wear behavior of denture teeth made of inorganically filled polymers of chemical composition similar to that of Artglass. Jooste et al[28] studied such denture teeth and found the mean wear of the entire occlusal surface to be 94 µm for SR-Orthosit-PE (Ivoclar Vivadent) and 169 µm for Vitapan (Vita Zahnfabrik) after 3 years in service. These wear values were calculated from the quotient of volumetric wear (mm^3) and surface area (mm^2). The present study's finding that wear is affected by location (canine, premolar, molar) confirms the observations of other clinical studies.[22,27]

Despite the wear recorded, stable static occlusal contacts were observed for the Artglass crowns tested in this investigation. This was shown by Rammelsberg et al[14] with the same study population and suggests either that wear-related height loss was compensated by elongation or that neighboring natural teeth were subject to similar wear. Data on the wear of natural enamel vary substantially. One study showed the mean wear of occlusal contact areas to be 29 to 38 µm per year for natural molars and 15 to 18 µm for natural premolars.[22] Another publication found mean wear of the occlusal surfaces of premolars and molars of approximately 15 to 16 µm after 2 years.[29]

Conclusions

Although natural control teeth in the study population were not used in this study, the findings suggest that the wear resistance of modern ceramic-filled polymers does not match that of natural enamel. The materials normally used for crowns—metal alloys and ceramics—show wear behavior reported to be unproblematic[16,30] and definitely set the standard for ceramic-filled polymer crowns. In vitro data for the wear behavior of dental restoratives[9,17–21] and the wear measured in this clinical study should be taken into account when restoring complete occlusal surfaces with ceramic-filled polymers, and the wear behavior of ceramic-filled polymer crowns should be observed for a longer period of time. Nevertheless, it is regarded as established fact that all polymers and composites, in contrast with ceramics, have antagonist-friendly wear behavior, ie, the wear caused by the restorative on a natural antagonist is relatively low.[16,30]

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