Practice-based clinical evaluation of ceramic single crowns after at least five years

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Statement of problem. Long-term practice-based clinical evaluations of various contemporary ceramic crown restorations from multiple practitioners are limited.

Purpose. The aims of this study were to evaluate the clinical performance of ceramic single crowns and to identify factors that influence their clinical performance.

Material and methods. Ceramic single crowns that had been placed at the Mayo Clinic and in function since 2005 were identified and included in the study. The restorations were examined clinically, radiographically, and with photographs. Modified United States Public Health Services criteria were used for the clinical evaluation. The ceramic systems evaluated were bilayer and monolayer.

Results. Fifty-nine patients (41 women, 18 men) with 226 single teeth and implants restored with single ceramic crowns were identified. The mean duration from insertion date to study examination date was 6.1 years. Thirteen restorations (6%) were replaced at a mean 3.3 years after insertion date (range, 0.1-6.1 years). Estimated replacement-free survival rates (95% confidence interval [CI]; number of teeth/implants still at risk) at 5 years after insertion date were 95.1% (95% CI, 92.2-98.1; 153) and at 10 years were 92.8% (95% CI, 89.1-96.8; 8). The most common reason for replacement was fracture to the core of posterior layered ceramic crowns. The most commonly used luting agent was resin-modified ionomer cement. Most restorations exhibited clinically acceptable marginal integrity, shade, no caries recurrence, and no periapical pathology.

Conclusions. The clinical performance of ceramic single crowns at 5 and 10 years supports their application in all areas of the mouth. With the majority of fractures to the core occurring early in the lifetime of layered ceramic posterior crowns, consideration of other monolithic ceramic systems for posterior crowns is advised. (J Prosthet Dent 2014;111:124-130)

Clinical Implications
The long-term clinical performance of various ceramic systems placed by multiple practitioners in a group practice provides clinically based evidence of complications and the long-term management of these restorations.

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The fast-growing application of ceramic restorations in the past few decades has showed promising clinical applications for anterior teeth.1-5 Their desirable properties include improved esthetics, soft-tissue biocompatibility, chemical resistance to biodegradation,4 and reduced plaque accumulation.5,6 Various studies have investigated the long-term clinical performance of ceramic crowns.7-9 Several systems have been developed, but, because of their low fracture resistance and brittleness, their application has been mostly limited to anterior restorations. Reports on dental implant-retained ceramic single crowns, especially for posterior teeth continue to be limited by the small number of such restorations. Although events such as fracture rate, fracture location, caries, marginal integrity, root canal therapy or retreatment, and shade matching are routinely reported on, fracture of the ceramic crown remains the predominant complication.

Suggested factors that contribute to this finding include complex geometry, luting agent choice, ceramic system choice, and location in the arch.10-12 The luting agent choice is being studied more closely in vitro because the ceramic fracture strength decreases as the restoration ages and the bond strength degrades in the oral cavity. Resin cements are considered to improve the fracture resistance of ceramic restorations, but the long-term impact of degradation is difficult to explain.13 A recent in vitro comparison of various luting agents for ceramic restorations showed that conventional dual polymerized resin cements exhibited the least amount of nanoleakage compared with other resin cements and flowable composite resins.13

The 5-year survival rate of ceramic single crowns was estimated at 88.8% by a private practice provider,13 whereas a systematic review based on 34 articles showed an estimated 5-year survival of 93.3%.1 A more recent systematic review indicated an acceptable overall 5-year fracture rate of 4.4% for ceramic crowns irrespective of the ceramic materials used.1 The same systematic review suggested a higher fracture tendency for posterior crowns, with ceramic molar single crowns having a significantly higher fracture risk.1 The majority of fractures to the core have been reported to occur in the earlier years of a crown’s lifetime.13,15,16 which supports the theory that manufacturing flaws are not only the source of the fractures but also propagate until clinically detectable.

Some studies have demonstrated the similar clinical behavior of ceramic crowns and metal ceramic crowns.17-19 Few studies have discussed the biologic events, soft-tissue changes, or the need for root canal radiographic findings.20 Ceramic crowns have shown better soft-tissue tolerance and color match to adjacent natural teeth than metal ceramic crowns.21 With regard to implant-supported ceramic crowns, there is evidence that, regardless of the abutment or ceramic crown materials, the color of the soft tissue surrounding the implant ceramic crowns differs from that of natural teeth.22 Comparable wear of enamel opposing ceramic crowns and natural teeth has been shown,23,24 but reports are lacking on the wear on the ceramic crown itself. Whether factors such as opposing dentition or sex impact the clinical performance of ceramic single crowns is unknown. The aims of this study were to provide practice-based evidence of the clinical performance of single crown ceramic systems on natural teeth and dental implants in a prostodontic practice with multiple providers at the Mayo Clinic and to identify factors that may influence the long-term clinical performance of these restorations.

MATERIAL AND METHODS

Patients who had received treatment with a ceramic single crown at the Mayo Clinic Department of Dental Specialties, Division of Prosthetic and Esthetic Dentistry since 2005 were identified. The patients were contacted by letter and invited to participate in the study during their routine scheduled hygiene or follow-up appointments at the Mayo Clinic Dental Specialties Department. The patient population in the study was self-selected and did not receive any remuneration. The research protocol was approved by the Mayo Clinic Institutional Review Board.

The ceramic single crowns were evaluated clinically with bitewing and periapical radiographs and digital camera photographs. The study data were stored according to institutional policy. The following information was collected: patients’ age, sex, date of insertion, date of follow-up, complication(s) encountered until the date of follow-up, how complications were addressed, tooth or implant support of the ceramic crown, endodontic access, tooth foundation material, implant abutment type, ceramic system, crown substructure material, ceramic system, luting and/or bonding agent, and type of opposing dentition. The following parameters were evaluated with modified United States Public Health Services criteria: marginal integrity, fracture, the presence of cracks, secondary caries, shade, wear, and endodontic access. All of the ceramic single crowns that were replaced were considered a failure. A complication was defined as any grade other than A for the parameters of interest. All evaluators were calibrated. The ceramic systems included bilayer (alumina core, zirconia core) and monolayer (pressed lithium disilicate, zirconia).

Continuous parameters were summarized with means, medians, and ranges; categorical parameters were summarized with frequency counts and percentages. The comparisons among parameters of interest were evaluated by using the $\chi^2$ and Fisher exact tests. The replacement-free survival rates were estimated by using the Kaplan-Meier method. Statistical analyses were performed with the SAS software package (SAS Institute). All tests were 2-sided, and $P$ values <.05 were considered statistically significant.

RESULTS

A total of 59 patients with a mean age of 55 years (range, 16-85 years) and
226 single ceramic crowns on 183 natural teeth and 43 implants were evaluated (Table I). The mean follow-up time was 6.1 years (range, 5.1-12.9 years) from the date of insertion to the date of clinical evaluation. The distribution characteristics of the location and ceramic systems used are summarized in Table II. Seventy percent of ceramic crowns were located in the anterior or posterior maxilla. The majority of teeth did not have any foundation material. Most implant crown abutments were custom zirconia. The most commonly used luting-bonding agents were resin-modified glass ionomer cement, followed by resin cement and glass ionomer cement. None of the patients in this study needed endodontic therapy after crown placement.

**Fractures**

The 3 most common fracture locations were the incisal edge of anterior teeth (Fig. 1), followed by the distal marginal ridge and functional cusp. Of the 226 restorations, 27 (12%) experienced fractures, with 63% (n=17) extending to the core (Fig. 2) and requiring replacement. Overall, 7.4% of these fractures to the core occurred on posterior teeth. No fractures that prompted replacement of the crown occurred on implant-supported crowns. A statistically significant difference was found for fractures when the opposing dentition of natural teeth and fixed restorations were compared (P=.034). The fractures were most commonly (n=20 of 27 total fractures) noted when the opposing dentition was a fixed metal ceramic and resin metal restoration (tooth and implant restorations were combined for analysis). No statistical significance could be established (P=.27, Fisher exact test) when the differences in fractures among the ceramic systems were evaluated.

The marginal integrity of 3 restorations (1%) showed tactile and visual evidence of a marginal opening. No wear was noted in 87% of the ceramic crowns, whereas 4% (n=8) showed wear that extended to the core; this was noted only in the alumina core crowns in areas consistent with contact with the opposing dentition (Fig. 3). No statistically significant correlation of wear and type of opposing dentition was noted (P=.28). A statistically significant difference in wear (P<.001) of

**Table I.** Characteristics of restorations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. patients</td>
<td>59</td>
</tr>
<tr>
<td>Men</td>
<td>18</td>
</tr>
<tr>
<td>Women</td>
<td>41</td>
</tr>
<tr>
<td>Mean age at time of insertion, y</td>
<td>55</td>
</tr>
<tr>
<td>Total no. restorations</td>
<td>226</td>
</tr>
<tr>
<td>Teeth</td>
<td>183</td>
</tr>
<tr>
<td>Implants</td>
<td>43</td>
</tr>
<tr>
<td>Mean follow-up time, y</td>
<td>6.1</td>
</tr>
<tr>
<td>No. maxilla</td>
<td>165</td>
</tr>
<tr>
<td>Anterior</td>
<td>107</td>
</tr>
<tr>
<td>Posterior</td>
<td>58</td>
</tr>
<tr>
<td>No. mandible</td>
<td>61</td>
</tr>
<tr>
<td>Anterior</td>
<td>37</td>
</tr>
<tr>
<td>Posterior</td>
<td>24</td>
</tr>
<tr>
<td>Ceramic Systems, no. teeth (no. implants)</td>
<td></td>
</tr>
<tr>
<td>Alumina core layered</td>
<td>161 (31)</td>
</tr>
<tr>
<td>Zirconia core layered</td>
<td>14 (3)</td>
</tr>
<tr>
<td>Monolithic pressed</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Others*</td>
<td>2 (4)</td>
</tr>
</tbody>
</table>

*Zirconia, feldspathic, leucite reinforced, grouped due to small numbers.

**Table II.** Characteristics of replaced restorations

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Tooth</th>
<th>Type</th>
<th>System</th>
<th>Luting</th>
<th>Fracture Marginal Integrity</th>
<th>Wear</th>
<th>Opposing Dentition</th>
<th>Complication Addressed</th>
<th>Y*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maxillary right first premolar</td>
<td>T</td>
<td>Lava</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Natural</td>
<td>R1</td>
</tr>
<tr>
<td>1</td>
<td>Maxillary left lateral incisor</td>
<td>T</td>
<td>Lava</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R1</td>
</tr>
<tr>
<td>1</td>
<td>Maxillary left canine</td>
<td>T</td>
<td>Lava</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R1</td>
</tr>
<tr>
<td>2</td>
<td>Mandibular right lateral incisor</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R2</td>
</tr>
<tr>
<td>3</td>
<td>Mandibular right lateral incisor</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>B</td>
<td>B</td>
<td>Ceramic tooth</td>
<td>R3</td>
</tr>
<tr>
<td>4</td>
<td>Maxillary right lateral incisor</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Natural</td>
<td>R3</td>
</tr>
<tr>
<td>5</td>
<td>Maxillary right central incisor</td>
<td>I</td>
<td>Procera</td>
<td>RRGIC</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>Natural</td>
<td>R4</td>
</tr>
<tr>
<td>6</td>
<td>Maxillary left central incisor</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>Natural</td>
<td>R1</td>
</tr>
<tr>
<td>7</td>
<td>Maxillary right canine</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Natural</td>
<td>R3</td>
</tr>
<tr>
<td>8</td>
<td>Mandibular left first molar</td>
<td>T</td>
<td>Procera</td>
<td>Provisional</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R3</td>
</tr>
<tr>
<td>8</td>
<td>Mandibular left first premolar</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R3</td>
</tr>
<tr>
<td>9</td>
<td>Maxillary left first molar</td>
<td>T</td>
<td>Procera</td>
<td>RRGIC</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R3</td>
</tr>
<tr>
<td>9</td>
<td>Maxillary right first molar</td>
<td>T</td>
<td>Procera</td>
<td>Resin</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>Ceramic tooth</td>
<td>R5</td>
</tr>
</tbody>
</table>

T, tooth; RRGIC, resin-modified glass ionomer cement; R1, replace with different ceramic system; R2, replace substructure, replace with the same ceramic system; R3, replace with same ceramic system; I, implant; R4, remove failed implant; R5, replace substructure, replace with different ceramic system.

*No. of years in function until replacement.
the ceramic crowns was noted when anterior and posterior crowns were compared. Posterior teeth exhibited significantly less wear than anterior teeth. No caries was detected clinically or radiographically on any of the tooth crowns. The shade, assessed by visual and digital photography, was deemed to match the translucency as recorded at the time of insertion in 98% of the crowns. Two ceramic crowns on teeth had a shade mismatch in the normal range, and the patients did not object to them.

A natural opposing dentition was noted for 43% of patients (n=97) and a dentition with opposing fixed ceramic (metal ceramic or ceramic) and fixed metal resin prostheses for 53% of patients (n=119). A statistically significant difference was noted in the fracture of ceramic crowns opposing natural teeth and fixed tooth or implant-retained restorations (P=.034), with 74% of the fractures occurring when the opposing dentition was a fixed tooth or implant-retained restoration. Overall, 7% (n=16) of ceramic crowns demonstrated repairable complications, all of which were addressed without replacing the existing crown. How complications were addressed in the 13 teeth and implant ceramic crowns that were replaced is shown in Table II.

Soft-tissue recession was noted in 7% of the ceramic crowns, mostly on the labial surface of anterior maxillary and mandibular teeth. Significantly more recession (P=.02) was noted in anterior crowns than in posterior crowns. Erythema was found in 9% (n=21) of the ceramic crowns, with one-third of the erythema found around the entire tooth circumference.

The estimated replacement-free survival rate (95% confidence interval [CI]; number of restorations at risk) was 99.1% (95% CI, 97.8-100; 217) at 1 year after the insertion date, 96.7% (95% CI, 94.4-99.1; 204) at 3 years, 95.1% (95% CI, 92.2-98.1; 153) at 5 years, 92.8% (95% CI, 89.1-96.8; 72) at 7 years, and 92.8% (95% CI, 89.1-96.8; 8) at 10 years (Fig. 4 and 5). Of all 226 crowns, 13 (6%) required
replacement (Table II) at a mean of 3.3 years after the insertion date (range, 0.1-6.1 years). The most common reason for replacement was fracture to the core for 63% (n = 17). Only 1 implant crown was replaced due to the need for implant-body replacement to resolve symptomatic periapical pathology more than 5 mm. The replacement implant was restored with the same ceramic system.

Sex had no statistically significant impact on the parameters evaluated whether on a per patient (P = .32) or per crown (P = .082) basis.

DISCUSSION

In this study, the overall fracture rate of 12% was significantly higher than the recently reported (systematic review) rate of 4.4%, irrespective of the ceramic system used. The ceramic systems evaluated in this study and those previously reported varied greatly. Thus, data comparison by simply evaluating the reported percentages was insufficient.

In the present study, no statistical significance could be established (P = .27, Fisher exact test) in fractures among the ceramic systems. Reporting this finding in future studies is recommended to allow for data comparison among studies.

Factors such as follow-up time, luting agent, and time in function are important. In the present study, the majority of the ceramic crowns were layered and placed at least 5 years before the study’s clinical examination. The inclusion criterion in the systematic review was a mean average follow-up time of 3 years. The present study’s longer follow-up time combined with known decreased fracture strength that results from bond degradation may explain the higher than previously reported number of fractures. Another contributing factor is that the majority of ceramic crowns in this study were luted with resin-modified glass ionomer cement, which has been shown to provide inferior bond strength and nanoleakage resistance compared with resin cements.

In spite of the significantly higher overall fractures encountered in this study, the overall fractures to the core for posterior teeth (7.4% at mean 3.3 years) were very similar to those reported by Wang et al, who found an extrapolated fracture rate of 7.3% at a mean 3.3 years. This finding supports the observation defined by Groten and Huttig as “early mortality behavior” and may explain how higher and repetitive loading of these restorations in the posterior areas can lead to a clinically detectable fracture propagating from a manufacturing flaw in the ceramic crown at the time of insertion. This study provides further evidence to support the proposed phenomenon.

The majority of fractures occurred when the opposing dentition were natural teeth or ceramic restorations, this is an expected finding because the majority of these patients retained their natural dentition. Although evaluation of the opposing dentition is important, the selection of a ceramic system and adequate tooth reduction may ultimately be more clinically relevant. The replacement-free survival rate of the ceramic single crowns in function for at least 5 years in this study was 95.1% at 5 years and 92.8% at 10 years. This is slightly higher but consistent with the reported estimated survival rates of ceramic crowns in systematic reviews. Marginal integrity, shade, and caries were consistent with previous reports in the literature. The need for endodontic re-treatment after ceramic crown placement for only 1 tooth is
lower than the reported 4%. This 1 tooth showed endodontic radiographic periapical pathology greater than 5 mm. The patient was asymptomatic at the time of examination. None of the patients in this study needed endodontic therapy after crown placement.

Information on the soft-tissue margin condition at the time of crown insertion was not available. As a result, this can only be reported as a finding of the study clinical examination. A follow-up of these restorations may provide further evidence on whether this is an ongoing process. Additional reports in the literature are needed in this area. Factors that contribute to this finding may be the gingival displacement method, finish-line placement, and gingival biotype. When possible, finish lines were kept at or slightly occlusal to the gingival margin. The gingival displacement method was not standardized among consultants and resident prosthodontists for this patient population. No one specific gingival displacement protocol was applied at the practice because selection of the gingival displacement method is based primarily on patient need and provider preference. Protocols included a single-cord, double-cord technique, drug-impregnated, and nondrug-impregnated cords. The selection of the gingival displacement method was based on periodontal probing depths, tooth form, gingival biotype, and finish-line placement. When comparing the survival rates of different studies, researchers should consider the criteria used to calculate the estimated survival. Here, a replacement-free survival rate is shown to clarify such treatment options for patients and providers. This study found that several crowns on anterior teeth exhibited soft-tissue recession, especially when they opposed fixed tooth or implant-retained restorations.

As the oldest prosthodontic and multidental specialty practice in North America, the Mayo Clinic population data are unique in that they represent treatment from multiple prosthodontists and resident dentists. As a result, the findings of this study provide practice-based evidence of the clinical performance of the various ceramic systems introduced in the past 13 years for the restoration of single crowns. One of the limitations of this study was the low number of monolithic ceramic crowns, which limits the comparison of this ceramic system with layered systems; the monolithic material system started to be placed in the practice significantly later than layered systems. As a result, these crowns did not meet the established time follow-up of at least 5 years.

CONCLUSIONS

Based on the findings of this study:

1. Replacement-free survival rates of ceramic single crowns were 95.1% at 5 years and 92.8% at 10 years.

2. Fractures to the core of layered ceramic crowns for posterior teeth (7.4% at a mean 3.3 years) comprised the most common complication that prompted replacement of the ceramic crowns.

3. Further data that compare monolithic ceramic systems and layered systems for posterior applications are needed.

REFERENCES


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