A Total of 1,132 All-Ceramic Single-Tooth Restorations Show Acceptable Survival Rates up to 15 Years in a Non-University Setting

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Purpose: To evaluate the long-term survival of IPS Empress 2 and IPS e.max (Ivoclar Vivadent) restorations in a non-university setting. Materials and Methods: A retrospective study design was used to evaluate the survival rate of 1,132 Empress 2 and IPS e.max restorations placed in 251 patients with regard to patient age, gender, tooth type, tooth vitality, material, restoration form (inlay vs partial crown vs crown), cementation mode (self-adhesive vs non–self-adhesive), and bruxism activity. Kaplan-Meier and regression analyses were used for statistical analyses. Results: Of the 1,132 restorations, a total of 15 (IPS e.max = 3, Empress 2 = 12) failed. The overall survival rate for all restorations was 98.7% after 15.4 years. A significantly reduced survival rate was found for nonvital teeth (P = .002), patient age > 60 years (P = .002), crowns (vs inlays and partial crowns; P = .002), and self-adhesive resin materials (P = .018). Conclusion: Within the limitations of this study, glass-ceramic single-tooth restorations made of Empress 2 and IPS e.max show good survival rates up to a period of 15 years. Int J Prosthodont 2022;35:815–823. doi: 10.11607/ijp.7986

Due to their esthetics, biocompatibility, and good long-term survival rates, glass-ceramic single-tooth restorations are an integral part of restorative dental treatment.1–4 Their main shortcomings are the lack of mechanical stability and strength, which are primarily determined by the pronounced brittle fracture behavior and low tensile strength.5–7 The resultant fractures and chipping represent a significant challenge for practice and research. Nevertheless, great progress has been made in this field in recent decades. With the introduction of the leucite and lithium disilicate ceramics Empress 1 and 2 (Ivoclar Vivadent) at the end of the 1980s and the beginning of the 1990s, slow crack growth, which is particularly problematic for glass-ceramics, was significantly reduced by the incorporation of mechanically more stable leucite and lithium disilicate crystals.
While the material properties of glass-ceramic materials have improved the survival of restorations significantly, most studies do not consider further factors that are involved in the occurrence of complications and failures. For example, tooth-, patient-, and dentist-related factors, in addition to material-inherent influences, can have an impact on the survival of restorations. Thus, in addition to the known parameters (eg, restoration form and cementation mode) that influence the survival of glass-ceramic restorations, patient- and tooth-related factors (eg, age, bruxism activity, tooth position, and tooth vitality) should also be examined.

**MATERIALS AND METHODS**

The null hypothesis was defined as follows: Patient age, bruxism activity, tooth position and vitality, restorative material (Empress 2 vs IPS e.max [Ivoclar Vivadent]) and form (inlay vs partial crown vs crown), and cementation mode (self-adhesive vs non–self-adhesive) have no influence on the survival of glass-ceramic single-tooth restorations.

The aim of this study was to determine the survival rate of glass-ceramic single-tooth restorations in a non-university setting. Restorations placed between January 2000 and December 2015 were included. The inclusion criteria were: (1) glass-ceramic single-tooth restorations in the posterior region (first premolar to third molar) made from Empress 2 and IPS e.max; (2) a minimum of 2 years of follow-up; and (3) patients aged ≥ 18 years.

Medical charts were reviewed to determine patient age, treatment variables (tooth position, luting material, restoration form and material [Empress 2 or IPS e.max]), patient- and tooth-specific variables (bruxism activity, tooth vitality, sensitive tooth surfaces), and observation factors (time of placement, last follow-up, time of loss of restoration). The patients were divided into the following groups depending on age: 18 to 39 years; 40 to 59 years; and ≥ 60 years.

Bruxism was diagnosed and digitally documented using Axis 1 of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), using criteria such as pain in the masticatory muscles and temporomandibular joint, non–age-related abrasion facets, and facial pain.

The luting materials used included Variolink II (Ivoclar Vivadent), RelyX Unicem (3M ESPE), G-CEM (GC), PANAVIA SA (Kuraray), Filtek Supreme (3M ESPE), Tetric EvoFlow (Ivoclar Vivadent), and PermaCem (DMG Dental). The luting material could not be traced for all restorations (n = 60); therefore, the total number of restorations with regard to the aspect of self-adhesive vs non–self-adhesive cemented restorations was 1,074 for the retrospective data analysis.

Irreparable fracture of the ceramic was defined as restoration failure. Additional fracture of the tooth structure was not documented. Debonding was evaluated separately and was not included in the survival rate.

Complications during follow-up were defined as debonding of the restoration and bruxism. The study project was registered and approved by the Ethics Committee of the University of Bonn (274/20).

**Treatment Protocol**

All patients were treated in a general dental practice by the same dentist. All restorations were made in the practice’s own technical laboratory by the same dental technician. Before the start of treatment, the dental and periodontal status of each patient was recorded, and Axis I of the RDC/TMD was examined. Depending on the diagnosis, pretreatment in terms of professional tooth cleaning/periodontal therapy or functional therapy was carried out.

The treatment protocol was as follows. The preparation of inlays was performed with rounded internal angles. The preparation of partial crowns was conducted with the cusps included as a shoulder preparation, and the marginal design of the crowns was carried out as a circular chamfer preparation (or similar). The crowns were prepared at an angle of 4 to 6 degrees, with rounded inner edges and a pronounced chamfer preparation.

The impression was taken with Impregum (3M ESPE) as a double-mix impression with the double-thread technique. Registration of the bite position was made according to the requirements of the individual situation in maximum intercuspation or in centric relation using a polyvinyl siloxane material (Futar, Kettenbach Dental). The master model was made with suprastone extra hard plaster (Kerr). The restorations were waxed up with organic wax and embedded in IPS PressVest (Ivoclar Vivadent) overnight. The restorations were pressed in the EP600 Combi press furnace (Ivoclar Vivadent).

The enamel was etched with 30% to 40% phosphoric acid for 30 seconds before placement, and the restoration was conditioned with 5% hydrofluoric acid for 20 seconds. The restoration was placed using the adhesive system Syntac Classic (Ivoclar Vivadent) and one of the previously mentioned adhesive luting materials. If possible, the restoration was placed under a cofferdam. After cementation, the occlusion was examined and adjusted if necessary. The adjustment was performed with a diamond-coated ball or bud and polished with diamond-grit ceramic polishers (Komet Dental).

**Data Analysis**

The statistical evaluation was carried out with SPSS software for Windows, version 24.0 (IBM). Kaplan-Meier method was used for survival analysis with log-rank test. The parameters included patient age, tooth, and treatment variables (self-adhesive vs non–self-adhesive cementation), and observation factors (time of placement, last follow-up, time of loss of restoration) as covariates.
age, tooth vitality, tooth position, restoration form and material, bruxism activity, and luting agent (self-adhesive vs non–self-adhesive). Logistic regression analysis was performed to calculate the influence of the different observational factors on the survival rates of Empress 2 and IPS e.max restorations, in which the different observational factors favored the occurrence of a fracture. Debonding was descriptively evaluated in relation to the restorative material, restoration shape (crown, partial crown, inlay), and luting material (self-adhesive/non–self-adhesive) using chi-square test and Fisher exact test.

Correlation analyses were used to determine the association between debonding and the luting material, performed using Spearman correlation. Differences were statistically significant when \( P < .05 \).

RESULTS

A total of 1,132 restorations (IPS e.max = 363, Empress 2 = 769) placed in 251 patients were evaluated. The mean follow-up time was 6.6 ± 0.09 years (median 6.03, interquartile range [IQR] 3 to 9.6, range 2 to 15 years).

The mean age at time of placement was 51.46 ± 12.29 years for IPS e.max restorations and 46.6 ± 10.31 years for Empress 2 restorations. A total of 455 restorations (40.2%) were placed in male patients and 677 (59.8%) in female patients. From the 1,132 restorations, 331 (29.2%) were crowns (Empress 2 = 215, IPS e.max = 116), 487 (43.0%) were partial crowns (Empress 2 = 315, IPS e.max = 172), and 314 (27.7%) were inlays (Empress 2 = 239, IPS e.max = 75). A total of 967 teeth (85.4%) were vital and 65 (5.7%) were endodontically treated before the start of treatment. In total, 935 restorations (85.8%) were cemented with a non–self-adhesive material (Variolink II, Tetric EvoFlow, Filtek Supreme, or PermaCem), and 155 (14.2%) with a self-adhesive resin material (G-CEM, RelyX Unicem, PANAVIA SA).

The number of patients at the 5-year follow-up was 671 (59.3%), at 10 years was 211 (18.6%), and at 15 years was 27.3 times more likely than in non–endodontically treated ones.

Survival Rate of All Restorations

The overall 5-, 10-, and 15-year cumulative survival rates of the 1,132 restorations were 99.6% (4 fractures), 97.2% (12 fractures), and 95.1% (15 fractures), respectively (Table 1 and Fig 1).

Survival Rate in Relation to Restoration Material

The overall 5-, 10-, and 13.5-year cumulative survival rates of the 363 IPS e.max restorations were 99.2% (2 fractures), 96.6% (3 fractures), and 96.6% (3 fractures), respectively.

The overall 5-, 10-, and 15-year cumulative survival rates of the 756 Empress 2 restorations were 99.7% (2 fractures), 97.4% (10 fractures), and 95.3% (12 fractures) (Table 1 and Fig 2).

There was no significant difference in survival rate between Empress 2 and IPS e.max restorations (\( P = .072 \)).

Survival Rate in Relation to Patient Age

In the \( \leq 39 \)-year age group, 3 out of 121 restorations (0.2%) fractured. The 15-year survival rate was 94.1%.

In the 40–59-year age group, 5 of 647 restorations (0.5%) fractured, corresponding to a 15-year survival rate of 98.3%.

In the \( \geq 60 \)-year age group, 7 of 371 restorations (0.2%) fractured for a 15-year survival rate of 89.4%.

Restorations in the \( \geq 60 \)-year age group had a significantly higher failure rate than in the two younger age groups (\( P = .002 \)) (Table 1 and Fig 3). The chance for glass-ceramic restorations to fail in patients younger than 39 years was 0.83 times lower than in older patients (odds ratio [OR] = 0.832) but without statistical significance (\( P = .68 \)).

Survival Rate in Relation to Pretherapeutic Endodontic Treatment

Of the 1,132 teeth, 67 (5.9%) were endodontically treated, and 6 (40%) of the 15 fractures occurred after endodontic treatment. The 15-year survival rates for Empress 2 and IPS e.max restorations were significantly higher for vital than endodontically treated teeth (99.2% vs 91.0%, respectively; Table 1 and Fig 4). The regression coefficient was 27.3, with \( P < .001 \). Thus, the occurrence of fracture in endodontically treated teeth was 27.3 times more likely than in non–endodontically treated ones.

Survival Rate in Relation to Bruxism

Of the 193 (17.0%) restorations placed in patients without bruxism, one fractured, which corresponds to a 99.5% probability of survival. Of the 289 restorations placed in patients with severe bruxism, 4 (0.9%) fractured for a 15-year survival rate of 98.3%.

In the \( \leq 39 \)-year age group, 3 out of 121 restorations (0.2%) fractured for a 15-year survival rate of 94.1%.

In the 40–59-year age group, 5 of 647 restorations (0.5%) fractured, corresponding to a 15-year survival rate of 98.3%.

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98.9%, and for the third molars was 100% (Table 1 and Fig 6). With $P > .930$, the differences between tooth positions were not statistically significant.

### Survival Rate in Relation to Restoration Form

The 15-year survival rate of glass-ceramic crowns was 94.2%, of partial crowns was 89.6%, and of inlays was 100% (Table 1 and Fig 7). The failure rate of partial crowns was significantly higher than inlays and crowns ($P = .002$). Crowns failed mainly in the first 10 years after placement compared to partial crowns, which failed primarily after 10 years. However, the survival rate of partial crowns fell below that of crowns at 10 years after placement.

### Survival Rate in Relation to Cementation

The survival rate of restorations placed with non–self-adhesive materials (Variolink II, Tetric EvoFlow, Filtek Supreme, PermaCem) showed a survival rate of 98.8% after 15 years, and restorations placed with self-adhesive materials (G-CEM, RelyX Unicem, PANAVIA SA) showed a survival rate of 97.3% (Table 1 and Fig 8). Therefore, the survival rate of restorations placed with a non–self-adhesive luting material was $P = .018$, which

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### Table 1

<table>
<thead>
<tr>
<th>Observation factors</th>
<th>Restorations, n (%)</th>
<th>Fractures, n (%)</th>
<th>Fractures, n (survival rate, %) at 5 y</th>
<th>Fractures, n (survival rate, %) at 10 y</th>
<th>Fractures, n (survival rate, %) at 15 y</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>1142 (100)</td>
<td>15 (1.31)</td>
<td>4 (99.6)</td>
<td>13 (97.2)</td>
<td>15 (95.1)</td>
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</tr>
<tr>
<td><strong>Material</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Empress 2</td>
<td>765 (66.6)</td>
<td>12 (1.05)</td>
<td>2 (99.7)</td>
<td>10 (97.4)</td>
<td>12 (95.3)</td>
<td>.072</td>
</tr>
<tr>
<td>IPS e.max</td>
<td>363 (32.3)</td>
<td>3 (0.26)</td>
<td>2 (99.2)</td>
<td>3 (96.6)</td>
<td>3 (96.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>≤ 39</td>
<td>121 (10.6)</td>
<td>3 (0.2)</td>
<td>3 (94.1)</td>
<td>3 (94.1)</td>
<td>3 (94.1)</td>
<td>.002</td>
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<tr>
<td>40–59</td>
<td>647 (56.8)</td>
<td>5 (0.4)</td>
<td>1 (99.0)</td>
<td>5 (98.3)</td>
<td>5 (98.3)</td>
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<tr>
<td>≥ 60</td>
<td>371 (32.5)</td>
<td>7 (0.6)</td>
<td>1 (99.7)</td>
<td>5 (96.1)</td>
<td>7 (89.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Endodontic treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No endodontic treatment</td>
<td>1078 (94.3)</td>
<td>9 (0.8)</td>
<td>2 (99.8)</td>
<td>7 (98.3)</td>
<td>9 (98.2)</td>
<td>.000</td>
</tr>
<tr>
<td>Endodontically treated</td>
<td>67 (5.86)</td>
<td>6 (0.5)</td>
<td>2 (96.3)</td>
<td>6 (62.5)</td>
<td>6 (62.5)</td>
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<tr>
<td><strong>Bruxism</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No bruxism</td>
<td>193 (79.4)</td>
<td>1 (0.08)</td>
<td>0 (100)</td>
<td>1 (98.5)</td>
<td>1 (98.5)</td>
<td>.099</td>
</tr>
<tr>
<td>Bruxism</td>
<td>743 (20.6)</td>
<td>13 (0.011)</td>
<td>4 (99.4)</td>
<td>11 (95.2)</td>
<td>13 (90.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Tooth position</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First premolar</td>
<td>268 (23.5)</td>
<td>1 (0.08)</td>
<td>0 (100)</td>
<td>1 (98.4)</td>
<td>1 (98.4)</td>
<td></td>
</tr>
<tr>
<td>Second premolar</td>
<td>275 (24.1)</td>
<td>6 (0.5)</td>
<td>2 (99.2)</td>
<td>6 (94.4)</td>
<td>6 (94.4)</td>
<td>.284</td>
</tr>
<tr>
<td>First molar</td>
<td>272 (23.8)</td>
<td>5 (0.4)</td>
<td>1 (99.6)</td>
<td>3 (97.6)</td>
<td>5 (89.0)</td>
<td></td>
</tr>
<tr>
<td>Second molar</td>
<td>265 (23.2)</td>
<td>3 (0.3)</td>
<td>1 (99.5)</td>
<td>3 (98.0)</td>
<td>3 (98.0)</td>
<td></td>
</tr>
<tr>
<td>Third molar</td>
<td>65 (5.7)</td>
<td>0 (0)</td>
<td>0 (100)</td>
<td>0 (100)</td>
<td>0 (100)</td>
<td></td>
</tr>
<tr>
<td><strong>Restoration</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crown</td>
<td>331 (29.2)</td>
<td>10 (3.0)</td>
<td>4 (98.7)</td>
<td>10 (94.2)</td>
<td>10 (94.2)</td>
<td>.002</td>
</tr>
<tr>
<td>Partial crown</td>
<td>487 (43.0)</td>
<td>5 (1.0)</td>
<td>0 (100)</td>
<td>3 (97.3)</td>
<td>5 (89.6)</td>
<td></td>
</tr>
<tr>
<td>Inlay</td>
<td>314 (27.7)</td>
<td>0 (0)</td>
<td>0 (100)</td>
<td>0 (100)</td>
<td>0 (100)</td>
<td></td>
</tr>
<tr>
<td><strong>Cementation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non–self adhesive</td>
<td>926 (81.1)</td>
<td>11 (1.2)</td>
<td>1 (99.91)</td>
<td>9 (97.1)</td>
<td>11 (95.0)</td>
<td>.018</td>
</tr>
<tr>
<td>Self-adhesive</td>
<td>146 (12.8)</td>
<td>4 (2.7)</td>
<td>3 (97.6)</td>
<td>4 (96.5)</td>
<td>4 (96.5)</td>
<td></td>
</tr>
</tbody>
</table>

Kaplan-Meier and log-rank test was used to analyze differences between variables. Statistically significant $P$ values ($P < .05$) are indicated in bold.
was significantly higher than restorations placed with a self-adhesive cement.

Descriptive Evaluation of Debonding and Correlation Analysis

Of the 1,132 restorations evaluated, 9 debonded. All debonded restorations were Empress 2 crowns. No inlays, partial crowns, or any IPS e.max restoration showed debonding. No statistical significance was found between the materials ($P = .065$), but one was found for restoration form ($P < .001$). Of the 926 restorations placed with a non–self-adhesive luting material, 7 debonded, and 2 of the 144 restorations placed with a self-adhesive luting material debonded ($P = .352$, Table 2).

No correlation was found ($r = 0.001; P = .979$) between the debonding of a restoration and the individual luting material.

Regression Model

Cox regression analysis showed that endodontic treatment of the abutment teeth had a significant effect ($P < .001$) on the survival rate of glass-ceramic restorations. The failure rate of glass-ceramic restorations on
Fig 3  Kaplan-Meier estimate of cumulative survival rate by years after placement according to patient age.

Fig 4  Kaplan-Meier estimate of cumulative survival rate by year after placement according to endodontic treatment.

Fig 5  Kaplan-Meier estimate of cumulative survival rate by year after placement according to bruxism.

Fig 6  Kaplan-Meier estimate of cumulative survival rate by year after placement according to tooth position.

Fig 7  Kaplan-Meier estimate of cumulative survival rate by year after placement according to restoration form.

Fig 8  Kaplan-Meier estimate of cumulative survival rate by year after placement according to cementation mode.
endodontically treated teeth increased by a factor of 27 (OR = 27.23, 95% CI = 7.54 to 98.78) compared to the failure rate on non–endodontically treated teeth.

**Correlation Analysis**

No correlation could be found between restoration debonding and luting material (r = 0.001; P = .979).

**DISCUSSION**

The null hypothesis regarding the survival rates of Empress 2 and IPS e.max restorations in relation to endodontic treatment, patient age, and self-adhesive luting material was rejected. However, regarding material (Empress 2, IPS e.max), bruxism, and tooth position, the null hypothesis was accepted.

The survival rates for IPS e.max after 13.5 years and Empress 2 after 15 years were 96.6% and 95.3%, respectively. The material showed no significant influence on survival rate (P = .072). The results found in the present study for IPS e.max restorations are consistent with those reported in the literature. Two prospective studies determined survival rates for IPS e.max crowns of 100% after 5 years11 and 95.5% after 10 years.12 A retrospective study found an 8-year survival rate of 94.8%.13

The survival rate for Empress 2 restorations in the present study was 95.3% after 15 years and thus mostly in accordance with the literature. Malament et al4 revealed an overall survival rate for IPS e.max restorations of 96.49% after 16.9 years. El-Mowafy and Brochu14 reported retrospective survival rates between 96% and 91% after 4.5 to 7 years for Empress 2 inlays and onlays, and of 92% to 99% after 3 to 3.5 years for crowns. Prospective studies have reported between 84.4% and 75.9% after 11 years15 and 15 years,16 respectively.

The conflicting results in the literature might be attributed to differences in the definition of failure rate. In some studies, failure was defined as any event that led to replacement or recementation of the restoration, including secondary caries and debonding. In the present study, only fractures that led to a new restoration were defined as failures.

The present study did not document whether the fracture was the sole fracture of the restoration or whether there was an additional fracture in the tooth substance, which can occur particularly in cases of partial crowns and inlays.17,18 As this may provide important information on the causes of the restoration failure, this should be documented in future studies.

In the present study, older age proved to be a significant factor influencing the failure of glass-ceramic restorations (P = .002).

The literature on this subject is rare and inconsistent. While Malament et al4 determined no influence of patient age in their prospective long-term study on the survival of glass-ceramic restorations, De Backer et al19 showed that patients with irreversible complications were on average 4.5 to 5.5 years older than patients without complications. The influence of patient age on the survival of glass-ceramic restorations should be investigated in future studies.

In accordance with the literature,20,21 tooth vitality had a significant influence (P < .001) on restoration survival in the present study. After 10 years, a survival rate of 98.3% was found for vital teeth compared to 62.5% for endodontically treated teeth. The failure rate in endodontically treated teeth was 27.3 times higher than in vital ones.

A prospective 15-year study showed that pressed glass-ceramic restorations on endodontically treated teeth had a 19% higher probability of failure than on non–endodontically treated teeth.16 Several studies suggest that endodontically treated teeth are influenced by the access cavity design,22 the remaining residual walls,23 and the restoration.24 A narrow cavity design, a higher number of residual walls, and the restoration of endodontically treated teeth with a crown instead of direct resin restorations positively influence the survival of endodontically treated teeth.22–24 In the present study, all endodontically treated teeth were restored with a crown or partial crown. In further studies, the residual tooth substance and the insertion of a post should be documented in order to evaluate the cause of fracture.

The survival rate of glass-ceramic restorations in patients with bruxism (90.6%) after 15 years was lower than in patients without bruxism (98.5%), but without statistical significance (P = .099).

According to the current consensus of the assessment of bruxism, polysomnography for sleep bruxism and an electromyographic examination for waking bruxism are necessary for a definitive diagnosis.25 A limitation of the present study is that Axis I of the RDC/TMD and self-report served as diagnostic tools for bruxism, which only determined probable bruxism.25 The literature concerning survival rates of glass-ceramic restorations in patients with bruxism is inconsistent. Several studies16,26 report a positive correlation between parafunctional activities and a reduced survival rate of ceramic restorations, but this could not be confirmed in a recent meta-analysis.27 It should be taken into account that many studies deal with inconsistencies in the diagnosis of bruxism. Reliable bruxism screening would therefore be recommended for future studies.

In the present study, it was shown that the tooth position of the restoration (first premolar, second premolar, first molar, second molar, third molar) had no significant influence on the survival rate of the glass-ceramic restorations (survival rates 89.0% to 100%, P = .284), although first molars showed the lowest survival rates. This is in accordance with the literature. Malament et al4
determined slightly lower survival rates for glass-ceramic restorations on molars compared to premolars and canines, but without statistical significance, and Heinze and Rousson showed that adhesively luted Empress 2 crowns on anterior teeth and premolars had a lower fracture rate than on canines and molars.

Despite the higher fracture rate of crowns \( n = 10 \) compared to partial crowns \( n = 5 \) and inlays \( n = 0 \), the Kaplan-Meier survival rate was significantly lower for partial crowns (89.6%) after 15 years when compared to crowns (94.2%) and inlays (100%). The results of this study suggest that partial crowns have better survival rates than crowns in the short and medium term but perform worse in the long term. These results contradict literature that found no significant differences between restoration forms or only slightly lower survival rates for crowns than for inlays and partial crowns. The reasons for the reduced survival rate of partial crowns in the present study are unclear. Besides inherent material defects, sufficient material layer thickness, and the adhesive bonding used, the correct preparation also influences the clinical success of glass-ceramic restorations. Due to the retrospective study approach, it is not possible to reproduce the material layer thicknesses and material-appropriate preparations.

In accordance with the literature, restorations cemented with non–self-adhesive cements in the present study showed a significantly higher survival rate \( P = .018 \) than restorations cemented with self-adhesive cements (98.8% vs. 97.3%). No correlation was found between the debonding of a restoration and the luting material used (correlation coefficient of 0.001, \( P = .979 \)). The literature shows that the bond strength of non–self-adhesive material is higher than self-adhesive material, that the fracture rate of glass-ceramic restorations cemented with non–self-adhesive material is lower compared to restorations cemented with self-adhesive material, that dual-curing adhesive materials achieve higher bond strength than autopolymerizing materials, and that selective enamel etching increases the bond strength. The ease of use and the reduced postoperative sensitivity of self-adhesive resin cements counteract the slightly higher bond strength and survival rate of restorations cemented with a non–self-adhesive material. Selection of the luting material should be made according to the individual requirements of the tooth, the restoration, the dentist, and the patient.

In the present study, nine Empress 2 crowns debonded, and no IPS e.max restorations debonded. The difference between restorations was statistically significant for Empress 2 restorations \( P = .001 \), whereas there was no significant difference with respect to the restoration or luting material (self-adhesive vs non–self-adhesive). In the literature, few comparable studies exist so far. Van den Breemer et al showed that the bond strength of glass-ceramic restorations was significantly lower when the bond was purely to dentin compared to enamel. The dentin wound is greatest when crowns are prepared, and the wound decreases (ie, there is less structural damage) from the partial crown to the inlay. This may potentially explain the higher debonding rates of the Empress 2 crowns determined in the present study.

**CONCLUSIONS**

The probability of survival of IPS e.max and Empress 2 restorations was significantly lower on endodontically treated teeth than on non–endodontically treated teeth. The survival rate for partial crowns was lower than for crowns and inlays, and restorations cemented with self-adhesive materials showed lower survival rates than those cemented with non–self-adhesive resin materials. No significant differences were found with regard to material, patient age, bruxism, or tooth position. Both Empress 2 and IPS e.max restorations showed very good survival rates and an acceptable level of complications in a nonclinical setting.

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**REFERENCES**