Complete crowns in the posterior region are common in patients with severe loss of tooth structure due to caries or trauma and after endodontic treatment. Although cast gold and metal ceramic restorations have proven their long-term reliability and durability, clinicians and patients are currently attracted to more natural-looking alternatives. Restorations based on yttrium-oxide-stabilized tetragonal zirconia polycrystals (Y-TZP) have become popular because of their excellent mechanical properties, biocompatibility, and good esthetics when veneered with porcelain. Several studies of zirconia-based restorations have shown acceptable survival rates, but almost all also report chipping or veneering material fractures of the porcelain.

Depending on its magnitude and location, a small veneering material fracture may require a simple adjustment of the restoration through polishing or repair with composite resin. However, if the damage grossly alters the esthetic appearance or leads to the loss of occlusal or proximal contacts, the restoration may need to be replaced. The use of veneering ceramics with a CTE (coefficient of thermal expansion) as close as possible to that of the zirconia core, anatomically supporting frameworks, and slow heating and cooling rates during the veneering process have been shown to reduce the incidence of chipping.

Other solutions to this shortcoming include the elimination of esthetic layering by using monolithic crowns made from a more translucent high-strength material. Instead of building up the porcelain in several layers and firing in multiple firing cycles, a single
Clinical Implications

The use of feather-edge preparations in combination with monolithic lithium disilicate single crowns on posterior teeth cemented with either self-adhesive resin cement or glass ionomer cement was associated with high survival rates during the observation period.

Material is used to fabricate the restoration. The esthetics of monolithic crowns can be individualized by using staining techniques.

A modified lithium disilicate material has been introduced (IPS e.max Press; Ivoclar Vivadent AG) whose intrinsic mechanical and esthetic properties seem to be clinically suitable for the fabrication of single crowns on posterior single crowns. It is available both as an ingot that can be pressed or as a solid block that can be milled with computer-aided design and computer-aided manufacturing (CAD/CAM) technology (IPS e.max CAD: Ivoclar Vivadent AG). The pressable material has become a popular dental restorative because of its precision, good mechanical properties, and translucency.

In vitro testing of this material suggested that monolithic lithium disilicate restorations can be more fatigue resistant than veneered zirconia. Clinical testing has also shown promising results in terms of short- to medium-term survival rates, esthetic outcome, and wear-friendliness to opposing enamel. Monolithic restorations made with this material can be either adhesively or nonadhesively cemented, as clinical studies and in vitro testing have reported no relevant differences between the 2 modes of cementation.

Traditional ceramic systems require adequate clearance to achieve proper esthetics and strength of the restoration. The typical recommendation for preparing teeth for ceramic crowns is a rounded shoulder, or heavy chamfer, with a facial tooth reduction up to 2 mm considered appropriate. These deep-shoulder mar-

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fatigue resistant than veneered zirconia. Clinical studies and in vitro testing have reported no relevant differences between the 2 modes of cementation.

A total of 257 monolithic lithium disilicate crowns with feather-edge margins were cemented with 2 different cements. The crowns were placed by 2 private dental practices between January 2009 and December 2014 (Table 1) in a total of 168 patients. The distribution of crowns by tooth position is reported in Table 2. All restora-
tions were evaluated during follow-up appointments between January and July 2015. The clinical evaluation (Table 3) was performed according to the modified California Dental Association (CDA) criteria.

Both operators (J.H.S. and M.B.) followed similar clinical procedures for tooth preparation, using the same armamentarium. Teeth were prepared with a vertical (feather-edge) margin. A reduction of at least 1 mm was made along the axial walls and approximately 0.3 mm at the margins, with flame-shaped diamond rotary instru-
ments (862.12, 862.16, 8862.12; Brasseler-Komet). The finish line was placed at gingival level or up to 1 mm apical to the free gingiva. Abutments were also reduced by 1.5 mm at the occlusal surface, with a convergence angle of approximately 6 to 10 degrees to provide adequate strength for the restoration.

Interim crowns were fabricated and luted with eugenol-free zinc oxide eugenol cement (Temp Bond NE; Kerr Corp). Impressions were made approximately 2 weeks after tooth preparation. A double displacement cord technique was used (Ultrapack; Ultradent Products Inc), and impressions were made with a polyether impression material (Impregum Penta; 3M ESPE) with a single viscosity procedure.

MATERIAL AND METHODS

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The clinical fit of the restorations was verified with a silicone material (Fit Checker Black; GC America Inc). Undesirable pressure spots on the intaglio surface were removed before cementation. Cementation was the only procedure carried out differently by each clinician. Crowns (n=124) placed by J.H.S. were cemented with self-adhesive resin cement. The intaglio surface of the crown was etched for 20 seconds with hydrofluoric acid, and a silane coupling agent (Clearfil Ceramic Primer; Kuraray Noritake Dental Inc) was then applied before the application of a self-etching resin-based cement (Rely-X Unicem 2; 3M ESPE). The tooth surface was cleaned with pumice on a rotary brush at low speed, and a 2% chlorhexidine solution (chlorhexidine digluconate 20% solution diluted 1:10 in distilled water; Caesar & Loretz GmbH) was applied before cementation. Isolation was obtained with the split dam technique or with cotton rolls whenever appropriate. The resin cement was mixed according to manufacturer instructions, the crown was seated, and the excess cement was light polymerized for 5 seconds. Excess cement was removed, and cement was light polymerized for an additional 60 seconds.

Crowns placed by the other operator (n=133 [M.B.]) were cemented with conventional glass ionomer cement (Vivaglas; Ivoclar Vivadent AG). The intaglio surfaces of the crowns in this group, as well as the tooth surfaces, were cleaned with hydrogen peroxide before the application of the glass ionomer cement, which was mixed according to manufacturer’s instructions. The working area was isolated with cotton rolls, and aluminum foil was applied over the seated crown to avoid contact with moisture until the cement had set completely. Excess cement was removed, and cement was light polymerized for an additional 60 seconds.

All patients were enrolled in a maintenance program every 3 to 6 months according to their periodontal condition. During regular maintenance appointments between June and December 2014, the crowns were visually inspected for chips, cracks, or fractures, and marginal integrity was evaluated with a sharp dental explorer (XP23/UNC12; Hu-Friedy). Data were gathered according to the modified CDA criteria for color match, porcelain surface, marginal discoloration, and integrity and further evaluated with descriptive statistics. Patients’ satisfaction was assessed using nominal scores (non-acceptable, acceptable, good, and excellent). In the case of any mechanical complication, the restoration was considered a failure.

**RESULTS**

Three of the crowns fractured and were classified as failures: 1 failed during cementation in the resin cement group, 1 failed after 2 months in a patient in the glass ionomer cement group, and 1 failed after 4 years of service in the glass ionomer group.

One mandibular molar crown in the resin cement group required endodontic treatment because of hypersensitivity. The access cavity was restored with composite resin, and the crown remained functional; it was not considered a failure. Therefore, at the time of clinical evaluation, 254 of the initial 257 crowns were available for evaluation (Table 2). No loss of retention was observed during the observation period (Table 1, mean ±SD of 24 ±13.6 months; range, 5-75 months). Clinical ratings of the monolithic crowns are reported in Table 3. The color match was rated excellent for 230 crowns, and the surface and anatomic form were rated excellent for 248 crowns; 6 crowns showed minor wear and a dull appearance and were polished chairside. A total of 245 crowns were rated excellent for marginal discoloration and 252 for marginal integrity. No surface chipping was noted. The color match was the lowest rating recorded, at 90.5%. All alpha scores were approximately 97% or above, indicating no appreciable change in the crowns in the observed sample. Representative crowns are shown in Figures 1-3.

### Table 1. Distribution of molars or premolars and number of patients with posterior crowns included

<table>
<thead>
<tr>
<th>Year</th>
<th>Resin Cement Group</th>
<th>Glass Ionomer Cement Group</th>
<th>Both Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Premolar</td>
<td>Molar</td>
<td>n Patients</td>
</tr>
<tr>
<td>2009</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>9</td>
<td>18</td>
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</tr>
<tr>
<td>2013</td>
<td>19</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>2014</td>
<td>8</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>80</td>
<td>92</td>
</tr>
</tbody>
</table>

### Table 2. Mean outcome percentages for each group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Resin Cement Group</th>
<th>Glass Ionomer Cement Group</th>
<th>Both Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>6-75</td>
<td>6-68</td>
<td>6-75</td>
</tr>
<tr>
<td>Mean no. of months</td>
<td>23.1</td>
<td>25.5</td>
<td>24.0</td>
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<tr>
<td>SD (months)</td>
<td>±12.7</td>
<td>±14.9</td>
<td>±13.6</td>
</tr>
<tr>
<td>CSR (%)</td>
<td>99.2</td>
<td>98.5</td>
<td>98.8</td>
</tr>
</tbody>
</table>

CSR, cumulative survival rate.
DISCUSSION

In this study, monolithic lithium disilicate crowns were associated with high short-term success rates (close to 99%) during the observation period, comparable with available data reported in other studies.\textsuperscript{15,16} In an effort to reduce the biological cost without compromising the esthetic outcome of the crown (in this case, biological cost was the removal of sound tooth structure), a high-strength ceramic material was selected in combination with feather-edge margin geometry. This type of cervical margin design has been shown to provide excellent marginal integrity with veneered zirconia partial fixed dental prostheses and crowns.\textsuperscript{5,6,12,14}

Various investigators have shown that such vertical margins bring the procedural advantages of easier impression making, even for multiple abutments, and improved marginal adaptation after cementation.\textsuperscript{33-36} No differences in periodontal health have been demonstrated among different geometric patterns of margin designs, and the crown margins in teeth restored with feather-edge margins have influenced gingival conditions no more than natural teeth in a sample of patients with periodontal disease.\textsuperscript{37-39}

Monolithic complete restorations in lithium disilicate have shown higher in vitro fracture loads than hand-layed zirconia restorations, with bulk fracture of the material seen only at high stress levels.\textsuperscript{13,20-22} Clinical reports suggest that this type of ceramic restoration is reliable,\textsuperscript{12-14} even at a reduced thickness.\textsuperscript{21,22}

Cortellini et al\textsuperscript{12} reported use of monolithic lithium disilicate crowns with feather-edge margin design. Considering only crowns in the posterior region, the 99 crowns cemented with a self-etching resin cement included in the study showed high survival rates, with few technical complications. Valenti and Valenti\textsuperscript{14} reported using 70 posterior monolithic and bilayered single lithium disilicate crowns cemented with a self-etching resin cement, confirming the good clinical performance of these restorations.

In the present study, one clinician cemented the restorations with conventional glass ionomer cement while the other used self-adhesive resin-based cement. No relevant clinical differences were found between the groups of restorations. Neither the type of cement nor the location of the crown (premolar versus molar) influenced the survival rate of the crowns.

Although feather-edge preparations are not specified for use with this material by the manufacturer, the manufacturer claims it can be pressed to form thin, preparationless veneers with a minimum thickness of 0.3 mm, which is compatible with the current study’s crown thickness at the margin. A recently published in vitro study showed that lithium disilicate ceramic crowns bonded to abutment teeth prepared with this type of margin resulted in a fracture strength similar to that of those bonded on abutments with a horizontal finish line.\textsuperscript{13}

The favorable results of in vitro\textsuperscript{13,20,21,23} and clinical studies\textsuperscript{12,14,15,21,22} suggest that the toughness and initial strength of monolithic pressed lithium disilicate is suitable for the fabrication of crowns in the posterior region. Nevertheless, there is a risk of subcritical crack formation and propagation, especially in the presence of moisture. Repetitive or long-term loading at low levels may cause preexisting subcritical defects within the restorative material to grow slowly until failure occurs.\textsuperscript{45,46} In theory, bulk fracture may occur even at a level of loading that was originally insufficient to cause failure of the prosthesis. In vitro studies have reported that a thickness of 1.5 mm or greater (similar to the restoration thickness

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A (%)</th>
<th>B (%)</th>
<th>C (%)</th>
<th>D (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color match</td>
<td>91.9</td>
<td>89.3</td>
<td>90.6</td>
<td>8.1</td>
</tr>
<tr>
<td>Surface</td>
<td>98.4</td>
<td>97.0</td>
<td>97.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>97.6</td>
<td>95.5</td>
<td>96.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Marginal Integrity</td>
<td>99.2</td>
<td>98.5</td>
<td>98.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

CDA, California Dental Association.

Figure 1. Monolithic crown on left mandibular second molar 39 months after cementation.

Table 3. Frequency distribution of clinical ratings according to modified CDA criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Resin Cement</th>
<th>Glass Ionomer Cement</th>
<th>Both</th>
<th>Resin Cement</th>
<th>Glass Ionomer Cement</th>
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<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin Cement</td>
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<td>C (%)</td>
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<td>8.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Surface</td>
<td>98.4</td>
<td>97.0</td>
<td>97.6</td>
<td>1.6</td>
<td>3.0</td>
<td>2.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>97.6</td>
<td>95.5</td>
<td>96.4</td>
<td>2.4</td>
<td>4.5</td>
<td>3.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Marginal Integrity</td>
<td>99.2</td>
<td>98.5</td>
<td>98.8</td>
<td>0.8</td>
<td>1.5</td>
<td>1.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
considered in this study) significantly increases the number of cycles needed for specimen failure. A sufficient restoration thickness in the occlusal region may be helpful in preventing the onset of crack formation and propagation. Unfortunately, limited clinical data are available regarding the medium to long-term survival of this type of restoration.

In the present study, 254 monolithic crowns with feather-edge preparations placed in 2 private dental practices gave favorable results, similar or superior to other short-term data reported for other margin designs and materials.

According to CDA evaluation criteria, the clinical quality of all crowns was within the satisfactory range. Patient satisfaction with the crowns was also high. No caries were detected, and no adverse soft tissue reactions around the crowns were observed. Margin integrity was rated excellent in virtually all crowns.

A few limitations of this retrospective study should be considered. Treatment was performed in 2 separate private practices by different clinicians following similar protocols but with different cementation procedures. The same type of margin was prepared with identical rotary instruments. In the dental laboratories, the lost wax technique and same pressed ceramic systems were used to fabricate the crowns. A direct comparison of the 2 groups of restorations reported was, nevertheless, impossible because the number of crowns per patient and group were different and placed at different times. Both groups, however, showed a low failure rate. All patients were well motivated and complied with maintenance appointments.

Results of the present study suggest that the clinical performance of monolithic lithium disilicate crowns with feather-edge margins is similar to that reported with other margin designs, although it required less removal of tooth structure. Existing recommendations to avoid knife-edge margins for lithium disilicate restorations were not supported by the study or by other clinical and in vitro studies. Despite such favorable and encouraging results, longer observation periods and randomized controlled trials are needed to compare the long-term effectiveness of lithium disilicate crowns fabricated with different marginal designs.

Figure 2. Crown on right maxillary first molar after 1 year. A, Occlusal view. B, Buccal view.

Figure 3. Crown on left maxillary second premolar after 10 months. A, Occlusal view. B, Buccal view.
CONCLUSIONS

Results from this retrospective evaluation suggest that for monolithic lithium disilicate, feather-edge margins yield clinical outcomes similar to those reported with other margin designs.

REFERENCES


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