Influence of Different Marginal Forms on Endodontically Treated Posterior Teeth Restored with Lithium Disilicate Glass-Ceramic Onlays: Two-Year Follow-up

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Purpose: To evaluate the clinical performance of endodontically treated (ET) teeth restored with two different marginal forms of lithium disilicate glass-ceramic (LDG ceramic) onlays. Materials and Methods: A total of 120 posterior teeth were prepared for onlays after ET. The occlusal surfaces of the teeth were removed 1.5 to 2 mm anatomically. Different marginal forms were employed depending on the thickness of the residual axis wall of each tooth: In Group S, a 1-mm shoulder was prepared when the remaining axis wall was > 2 mm (n = 50), and in Group B, a 20- to 30-degree bevel was prepared when the remaining axis wall was ≤ 2 mm (n = 70). The access of the pulp chamber was filled with resin, and 1.5 to 2 mm of the box morphology of the pulp chamber was preserved. The pressed LDG ceramic was applied to the fabricated onlays. The teeth and restorations were checked after 6, 12, and 24 months. All available restored teeth were assessed using modified United States Public Health Service criteria. Results: During the observation period, no tooth fracture occurred. Neither tooth cracks nor secondary caries were observed in Group S or Group B. The 2-year survival rate of the teeth was 100%. Five fractured onlays were observed in Group S in the molar region, while all onlays in Group B were intact (P < .05). The survival rate of the onlays was 95.83%. Conclusion: The results demonstrate that LDG ceramic onlays can preserve ET posterior teeth with a highly satisfactory outcome, though the marginal form may affect the survival rate of the onlay.


Onlays as indirect restorations have been proven to perform well in the long term.1–3 Onlays have been widely used to restore vital teeth with success rates of 93% to 97%.4–10 Ceramic systems provide good biocompatibility, anti-abrasion, and esthetic performance, and ceramic onlays are considered an efficient way to preserve tooth structure.

Currently, there is no consensus on whether an onlay can protect endodontically treated (ET) posterior teeth without a surrounding whole crown10,11; rather, it is widely accepted that the ET posterior tooth should be restored with a full crown.1,2,12,13 However, the preparation for a full crown leads to more tooth structure loss around the axis wall in addition to the already substantial loss of the ET posterior tooth structure due to dental caries, trauma, and the endodontic access preparation.2,14 The preparation of an onlay removes less tooth structure than for the preparation of a crown (45% vs 71%).15 By retaining better integrity, thickness, and quality, the remaining tooth structure might provide better fracture resistance.
cemented in 120 patients (37 men, 83 women; age 13 to 68 years, mean 25 years). A total of 42 restorations were prepared and cemented in maxillary posterior teeth (17 premolars and 25 molars), and 78 in mandibular posterior teeth (13 premolars and 65 molars). All patients were required to give written informed consent prior to their inclusion in the study.

Restoration Procedures
The restoration procedure was conducted by two of the authors (W.X. and C.C). All patients received onlay tooth preparation after root canal treatment. The tooth preparation was performed according to treatment standards using 80-μm diamond burs (EX-21 [ISO 237/021], BR-31 [ISO 001/018], TF-S21 [ISO 171/016]; MANI) and 25-μm finishing diamonds. Complete anatomical reduction of the occlusal surface was conducted. A reduction of 1.5 to 2 mm was checked and achieved. The form of the preparation was decided according to the thickness of the residual axis wall (Fig 1). The two different marginal forms for axis wall preparation were as follows:

• **Group S**: When the residual wall was > 2 mm, a 1-mm rounded shoulder margin was prepared along with a 1-mm–high axis wall (Fig 1a) (premolars, n = 12; molars, n = 38).
• **Group B**: When the residual wall was ≤ 2 mm, a flat bevel of 20 to 30 degrees was prepared without a shoulder (Fig 1b) (premolars, n = 18; molars, n = 52).

Neither kind of margin was directly exposed to occlusal contact. The external 20- to 30-degree bevel was prepared and formed in the same horizontal position as for the preparation of the shoulder.

There are few studies on the contour of onlays in restoring ET posterior teeth. The stress distribution, which is affected by the contour of restorations, contributes to the success of onlay-restored teeth. A favorable distribution of stress can be provided by completely covering the occlusal surfaces. Moreover, the marginal form can affect the marginal adaptation of a ceramic onlay. Ceramic onlays exhibit some marginal deficiency, as chipping of restoration margins has been clinically observed. Therefore, in the present study, different marginal forms of onlays were applied to restored ET teeth.

This study aimed to evaluate the clinical performance of ET teeth restored with lithium disilicate glass-ceramic (LDG ceramic) onlays. The research hypotheses were: (1) ceramic onlays would protect the ET tooth, and (2) the marginal form affects the success rate of an onlay-restored tooth.

**MATERIALS AND METHODS**

**Sample Size and Indication**
This study was approved by the Western China School of Stomatology Ethics Committee and was conducted in full accordance with the World Medical Association Declaration of Helsinki. Patients selected for this study met the following criteria: they had completed root canal treatment of a posterior tooth—which is characterized by extensive hard tissue loss—and were regarded as a candidates for full crown preparation; absence of periapical disease (both clinical and radiographic signs); possession of natural dentition without any restored or missing teeth; absence of any active periodontal disease; absence of hypomineralized enamel; and absence of bruxism. A total of 120 onlays were prepared and cemented in 120 patients (37 men, 83 women; age 13 to 68 years, mean 25 years). A total of 42 restorations were prepared and cemented in maxillary posterior teeth (17 premolars and 25 molars), and 78 in mandibular posterior teeth (13 premolars and 65 molars). All patients were required to give written informed consent prior to their inclusion in the study.

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Neither kind of margin was directly exposed to occlusal contact. The external 20- to 30-degree bevel was prepared and formed in the same horizontal position as for the preparation of the shoulder.
The bottom of the pulp chamber was sealed with 1 mm of glass-ionomer cement (Ketac Cem, 3M ESPE). The composite resin (Tetric N-ceram, Ivoclar Vivadent) was then applied to fill the occlusal box of the endodontic access. The pulpal floor was prepared 1.5 to 2 mm from the occlusal margin of the prepared tooth (Fig 1). Standardized preparations were performed using proximal boxes of 2 mm at the cervical wall in a proximal-proximal direction. The residual axis wall of enamel was removed when a crack existed or if the enamel was prone to fracture. All surfaces were smoothed, and line angles were rounded.

Full-arch impressions were taken using a polyvinylsiloxane material (Express, 3M ESPE). The interim prostheses were fabricated using self-curing acrylic resin (Luxatemp, DMG). All of the LDG ceramic onlays were fabricated by the same technician with IPS e.max Press (Ivoclar Vivadent) according to the manufacturer’s instructions. Restorations were heat pressed following the lost-wax technique.

The intraoral fits were evaluated under a rubber dam. Following adjustments, the internal surface of the LDG ceramic onlay was etched with 5% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent) for 20 seconds and then rinsed. The residual axis wall of enamel was removed when a crack existed or if the enamel was prone to fracture. All surfaces were smoothed, and line angles were rounded.

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Table 1  Modified USPHS Criteria

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rating</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth integrity</td>
<td>Alpha</td>
<td>Intact tooth structure without any cracks</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Visible crack with no mobile fracture or defect</td>
</tr>
<tr>
<td></td>
<td>Charlie</td>
<td>Visible defect or mobile fracture</td>
</tr>
<tr>
<td>Proximal contact</td>
<td>Alpha</td>
<td>Intact contact area with proper contact</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Light contact</td>
</tr>
<tr>
<td></td>
<td>Charlie</td>
<td>Open contact</td>
</tr>
<tr>
<td>Secondary caries</td>
<td>Alpha</td>
<td>No evidence of caries contiguous with the margin of the restoration</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Evident caries contiguous with the margin of the restoration</td>
</tr>
<tr>
<td>Anatomical form</td>
<td>Alpha</td>
<td>Intact anatomical contour</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Slight deviations from ideal performance, not harmful to the tooth or to the restoration</td>
</tr>
<tr>
<td></td>
<td>Charlie</td>
<td>Severe defect, replacement required</td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>Alpha</td>
<td>No visible evidence of ditching along the margin</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Dentin or base is exposed along the margin</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>Alpha</td>
<td>No discoloration on the margin between the restoration and the tooth structure</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Discoloration on the margin between the restoration and the tooth structure, can be refined</td>
</tr>
<tr>
<td></td>
<td>Charlie</td>
<td>Discoloration has penetrated along the margin of the restorative material in a pulpal direction, cannot be refined</td>
</tr>
<tr>
<td>Surface texture</td>
<td>Alpha</td>
<td>Smooth surface</td>
</tr>
<tr>
<td></td>
<td>Bravo</td>
<td>Slightly rough or pitted, can be refinished</td>
</tr>
<tr>
<td></td>
<td>Charlie</td>
<td>Rough, cannot be refinished</td>
</tr>
</tbody>
</table>

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The five onlays in Group S that exhibited fracture failure were all found in the molar region (Fig 2). No restoration failure existed in Group B, demonstrating better marginal integrity \((P < .05)\). Except for the fractured onlays, only one restoration achieved a Bravo rating for anatomical forms in Group B (Fig 3). The fracture pattern of the onlays was mainly observed along the margin of the functional cusps.

Marginal discoloration increased slightly after the 12-month recall, but all five restored teeth were considered clinically acceptable (Bravo) and refined (two in Group S and three in Group B, \(P > .05\)). The surface texture

### RESULTS

Tables 2 and 3 summarize the examination results according to the modified USPHS criteria. The recall rate of surviving restorations at each follow-up was 100%. All of the patients were satisfied with their restorations. Over the whole observation period, the survival rate of the teeth was 100%. There were no tooth fractures, cracks, or secondary caries in either group.

The survival rate of the onlays was 95.83%. In the premolar regions, the survival rate of the onlays was 100%, while the rate was 94.44% in the molar region \((P < .05)\). The five onlays in Group S that exhibited fracture failure were all found in the molar region (Fig 2). No restoration failure existed in Group B, demonstrating better marginal integrity \((P < .05)\). Except for the fractured onlays, only one restoration achieved a Bravo rating for anatomical forms in Group B (Fig 3). The fracture pattern of the onlays was mainly observed along the margin of the functional cusps.

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### Table 2

<table>
<thead>
<tr>
<th>Recall</th>
<th>Baseline (6 mo), n (%)</th>
<th>12 mo, n (%)</th>
<th>24 mo, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessed restorations</td>
<td>Alpha</td>
<td>Bravo</td>
<td>Charlie</td>
</tr>
<tr>
<td>Tooth integrity</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Proximal contact</td>
<td>115</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Secondary caries</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anatomical form</td>
<td>117</td>
<td>1</td>
<td>2(^{a})</td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>118</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>119</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Surface texture</td>
<td>119</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^{a}\)Two onlays (1.7%) received a Charlie rating at the 6-month recall (restoration fracture) and were located on two mandibular second molars.

\(^{b}\)Three onlays (2.5%) received a Charlie rating at the 1-year recall (restoration fracture) and were located on two maxillary first molars and one mandibular second molar.

\(^{c}\)Failed restorations at the last recall point were subtracted and not recalled again.

### Table 3

<table>
<thead>
<tr>
<th>Groups</th>
<th>Group S (n = 50)</th>
<th>Group B (n = 70)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bravo</td>
<td>Charlie</td>
</tr>
<tr>
<td>Tooth integrity</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Proximal contact</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Secondary caries</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anatomical form</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>6</td>
<td>–</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Surface texture</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Group S = remaining axis wall > 2 mm, 1-mm shoulder prepared; Group B = Remaining axis wall ≤ 2 mm, 20- to 30-degree bevel prepared.

### Fig 2

(Right) Onlay failure of a mandibular second molar observed at the 6-month recall in Group S. The fracture pattern was first located at the buccal-distal margin.
texture of the surviving onlays presented no obvious deterioration. Three restorations presented with slight change of proximal contact, but there was no requirement to replace these onlays.

**DISCUSSION**

The results of the present study support the two hypotheses, that (1) the LDG ceramic onlay protects ET teeth and (2) the marginal form affects the success rate of onlay-restored teeth.

According to the calculation of sample sizes prior to the start of the study, 116 samples were needed. A total of 120 patients and 120 teeth were included. Because the follow-up time was short, the recall rate was 100% during the observation period.

The survival rate of teeth was 100%. There was no tooth fracture or crack among all 120 restored teeth. Clinical studies on crown-restored ET teeth presented success rates of about 94% to 97% in the same observation period. Previous studies have proven that conservative preparation could benefit the restored teeth by preserving more residual tooth structure. The results of this study indicate that ceramic onlays were able to protect ET teeth.

The total cuspal coverage of the occlusal surface was shown to produce better resistance than partial coverage when a ceramic onlay was used, as it withstands the wedge force caused by the intracoronal part of the restoration. The infinite analysis showed that less coverage of the cusp could increase the horizontal stress in the dentin, which could yield and be fractured. Both the bevel and the short axis wall can not only wrap the cusp, but also reduce the amount of the tooth removed. Furthermore, with this method, the inward compression is produced by mastication. The risk of tooth fracture would be reduced as well; thus, the onlays in this study covered all the cusps of the tooth.

In the present study, restored teeth presented better outcomes in the premolar region than in the molar region ($P < .05$). The lower number of complications in the premolar region might be associated with different occlusal loads as well as the smaller loading area in this region. Meanwhile, Group B demonstrated better marginal integrity than Group S in the molar region ($P < .05$). The results of the infinite analysis showed that stress was concentrated along the occlusal-axis wall corner of the function cusp of the onlay while the shoulder was prepared. This stress concentration could increase the risk of ceramic fracture along the onlay margin, which was exposed to greater occlusal loads in the molar region and might explain the fracture failures of the onlays in Group S.

Some studies have suggested that the margin of the onlay should not be in places exposed to significant loads. In the present research, neither kind of margin was directly exposed to occlusal contact. The bevel was prepared at the same horizontal level as the preparation of the shoulder. As a result, a thicker pattern of onlay could be fabricated as the bevel was prepared. The results indicate that the external bevel may allow a better survival rate than the shoulder in the same horizontal position.

Additionally, the depth of the intracoronal pattern of the onlays may affect the fracture resistance of the restored teeth. The risk of fracture could increase when the intracoronal pattern of the onlay is located deep in the pulp chamber for retention. The need for a conventional means of retention, with respect to both the taper and the depth of the intracoronal pattern, was dramatically reduced when using the ceramic-enamel adhesive technique. A clinical study reported no significant difference between vital and nonvital teeth.
teeth restored with onlays with regard to fracture resistance when the pulp chamber of nonvital teeth was filled up with glass ionomer. The length of the intracoronar pattern of the onlay resulted in less compression stress on the dentin surrounding the cavity. Thus, in the present study, the pulp chambers of the restored teeth were filled with resin and glass ionomer.

Previous studies have shown that excellent marginal adaptation is able to prevent secondary caries. Marginal adaptation is associated with the integrity of the cementation and the restoration. In this study, the deterioration of marginal adaptation was mainly caused by marginal chipping or fracture of onlays, which led to a slight change in proximal contact. On the other hand, deterioration of marginal adaptation and secondary caries were seldom observed among surviving onlays.

In the present study, LDG ceramic was applied to fabricated onlays. The success rate of the restorations was 95.83%. In previous studies, different complications were observed 2 years after the teeth were restored. For example, the leucite-reinforced ceramic system evinced a deterioration of marginal integrity. Teeth restored with composite resin might suffer secondary caries or even fracture. Although the follow-up time for this study was short, its results indicate that LDG ceramic could be applied to onlay restorations.

CONCLUSIONS

Within the limitations of this study, at a mid-term observation, it appears that LDG ceramic onlays could preserve ET posterior teeth. The marginal form may affect the long-term survival rate of the onlay.

ACKNOWLEDGMENTS

The authors report no conflicts of interest.

REFERENCES

Clinical Research


Literature Abstracts

Post-Exercise Hypotension and Skeletal Muscle Oxygenation is Regulated by Nitrate-Reducing Activity of Oral Bacteria

Postexercise hypotension (PEH) is a common physiologic phenomenon leading to lower blood pressure after acute exercise, but how this intriguing response occurs is not fully understood. This study investigated whether the nitrate-reducing activity of oral bacteria is a key mechanism in triggering PEH. Following a randomized, double-blinded crossover design, 23 healthy individuals (15 men and 8 women) completed two treadmill trials at moderate intensity. After exercise, participants rinsed their mouths with antibacterial mouthwash to inhibit the activity of oral bacteria or with a placebo mouthwash. Blood pressure was measured before and 1 hour and 2 hours after exercise. The microvascular response to a reactive hyperemia test, as well as blood and salivary samples, were taken before and 2 hours after exercise to analyze nitrate and nitrite concentrations and the oral microbiome. As expected, in the placebo condition, systolic blood pressure (SBP) was lower (1 hour: –5.2 ± 1.0 mmHg; P < .001; 2 hours: –3.8 ± 1.1 mmHg, P = .005) after exercise compared to baseline. This was accompanied by an increase in the peak of the tissue oxygenation index (TOI) during the reactive hyperemia response was observed after exercise (86.1% ± 0.6%) compared to baseline levels (84.8% ± 0.5%; P = .010). On the other hand, the SBP-lowering effect of exercise was attenuated by 61% at 1 hour in the recovery period and was fully attenuated 2 hours after exercise with antibacterial mouthwash. This was associated with a lack of changes in circulatory nitrite (P > .05) and an impaired microvascular response (peak TOI baseline: 85.1% ± 3.1%; peak TOI postexercise: 84.6% ± 3.2%; P > .05). The diversity of oral bacteria did not change after exercise in any of these treatments. These findings show that nitrite synthesis by oral commensal bacteria is a key mechanism for inducing the vascular response to exercise over the first period of recovery, thereby promoting lower blood pressure and greater muscle oxygenation.


Three-Year Results of a Randomized Controlled Clinical Trial Using Submucosally Veneered and Unveneered Zirconia Abutments Supporting All-Ceramic Single-Implant Crowns

This study aimed to evaluate the influence of veneering of the submucosal part of zirconia abutments on biologic, radiographic, technical, and esthetic outcomes in single-tooth implant sites. A total of 20 patients each received a zirconia abutment to support an all-ceramic implant-supported crown. Patients were randomly assigned to either the test group (n = 10), in which the abutment was modified with a pink ceramic veneer, or to the control group (n = 10), in which no further submucosal customization was undertaken. Patients were followed up at baseline (after insertion of the final reconstruction) and yearly thereafter. Wilcoxon-Mann-Whitney test was used to evaluate the difference between the medians of the two groups, whereas Wilcoxon signed-rank test was used to calculate the differences per group. At 3 years, 18 patients could be recalled. The survival rates reached 100% (implant level) and 95% (restoration level). Two implant crowns experienced minor chipping, one in each group. No significant intergroup differences were observed regarding mucosa thickness. The width of keratinized tissue did not change significantly over time in either group. The radiographic evaluation showed no significant differences regarding marginal bone level at any time point between the groups. Changes over time reached –0.27 mm (SD 0.41, median –0.26) for the test group and –0.21 mm (SD 0.30, median –0.31) for the control group; statistical significance was not reached within or between the groups. Veneering of the submucosal part of zirconia abutments did not significantly influence biologic or technical outcomes in single-tooth implant sites followed up for 3 years.