

# Effect of incisal preparation design on the fracture strength of monolithic zirconia-reinforced lithium silicate laminate veneers

**Running title: PREPARATION DESIGN ON STRENGTH OF LAMINATES**

Carlos A. Jurado, DDS, MS <sup>1</sup>, Ramtin Sadid-Zadeh, DDS, MS <sup>2</sup>, Hidehiko Watanabe, DDS, MS <sup>3</sup>,

Craig E. Robbins, DMD <sup>4</sup>, Kelvin I. Afrashtehfar, DDS, MSc, Dr, FDS RCS, FRCDC <sup>5,6</sup>,

Nicholas G. Fischer, PhD <sup>7</sup>, Damian J. Lee, DDS, MS <sup>8</sup>

<sup>1</sup> Associate Professor, Department of Prosthodontics, The University of Iowa College of Dentistry and Dental Clinics, Iowa City, IA, USA. [carlosjurado85@hotmail.com](mailto:carlosjurado85@hotmail.com)

<sup>2</sup> Associate Professor, Assistant Dean, Department of Restorative Dentistry, University of Buffalo School of Dental Medicine, Buffalo, NY, USA. [rsadidza@buffalo.edu](mailto:rsadidza@buffalo.edu)

<sup>3</sup> Professor, Department of Restorative Dentistry, Oregon Health and Sciences University School of Dentistry. Portland, OR, USA. [watanabh@ohsu.edu](mailto:watanabh@ohsu.edu)

<sup>4</sup> Assistant Professor, Department of Restorative Dentistry, Oregon Health and Sciences University School of Dentistry. Portland, OR, USA. [robbinsc@ohsu.edu](mailto:robbinsc@ohsu.edu)

<sup>5</sup> Evidence-Based Practice Unit, Clinical Sciences Department, College of Dentistry, Ajman University, P.O. Box 346, Ajman City, United Arab Emirates.

<sup>6</sup> Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, 3010 Bern, Switzerland. [Kelvin.Afrashtehfar@unibe.ch](mailto:Kelvin.Afrashtehfar@unibe.ch)

<sup>7</sup> Fellow, Minnesota Dental Research Center for Biomaterials and Biomechanics, University of Minnesota School of Dentistry, Minneapolis, Minnesota, USA. [fisc0456@umn.edu](mailto:fisc0456@umn.edu)

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/jopr.13689](https://doi.org/10.1111/jopr.13689).

This article is protected by copyright. All rights reserved.

<sup>8</sup> Associate Professor and Director Advanced Prosthodontics Program, The Ohio State University College of Dentistry. Columbus, OH, USA. [lee.6221@osu.edu](mailto:lee.6221@osu.edu)

### Correspondence

Damian J. Lee, DDS, MS.

Advanced Prosthodontics Program

The Ohio State University College of Dentistry

2039L Postle Hall, 305 West 12<sup>th</sup> Avenue, Columbus, OH 43210-1267

[Email: lee.6221@osu.edu](mailto:lee.6221@osu.edu)

[Accepted March 27, 2023](#)

### Abstract

**Purpose:** This study aimed to assess the fracture resistance of monolithic zirconia reinforced-lithium silicate laminate veneers (LV) fabricated on various incisal preparation designs.

**Materials and Methods:** Sixty maxillary central incisors with various preparation designs were 3D-printed, 15 each,

including preparation for: 1) LV with feathered edge design; 2) LV with butt joint design; 3) LV with palatal chamfer; and 4) full-coverage crown. Restorations were then designed and manufactured from zirconia-reinforced lithium silicate (ZLS) following the contour of a pre-operation scan. Restorations were bonded to the assigned preparation using resin cement and following the manufacturer's instructions. Specimens were then subjected to 10,000 thermocycles at 5 °C to 55 °C with a dwell time of 30 seconds. The fracture strength of specimens was then assessed using a universal testing machine at a crosshead speed of 1.0 mm/min. One-way ANOVA and Bonferroni correction multiple comparisons were used to assess the fracture strength differences

This article is protected by copyright. All rights reserved.

between the test groups ( $\alpha = 0.001$ ). Descriptive fractographic analysis of specimens was carried out with SEM images.

**Results:** Complete coverage crown and LV with palatal chamfer design had the highest fracture resistance values ( $781.4 \pm 151.4$  N and  $618.2 \pm 112.6$  N, respectively). Single crown and LV with palatal chamfer had no significant

difference in fracture strength ( $p > .05$ ). LV with feathered edge and butt joint designs provided significantly ( $p < .05$ )

lower fracture resistance than complete coverage crown and LV with palatal chamfer design.

**Conclusion:** The fracture resistance of chairside milled ZLS veneers was significantly influenced by the incisal preparation designs tested. Within the limitation of this study, when excessive occlusal forces are expected, LV with

palatal chamfer display is the most conservative method of fabricating an indirect restoration.

**Keywords:** Silicates, Flexural Strength, Computer-Aided Design, Subtractive Computer-Aided Manufacturing

Chairside computer-aided design and computer-assisted manufacture (CAD-CAM) permits clinicians to precisely manufacture a wide array of materials, for provisional or definitive restorations, faster than the traditional methods.<sup>1-</sup>

<sup>7</sup> Recent studies have demonstrated that CAD-CAM restorations have a better marginal adaptation than conventionally

fabricated indirect restorations.<sup>8,9</sup> Similar to CAD-CAM complete coverage restorations, laminate veneers (LV) can

be fabricated using CAD-CAM technology where an intraoral scanner (IOS) is used to register the preparation, designed, then milled from a material of choice.<sup>10,11</sup> These restorations have shown to provide high esthetic results to fulfill patient demands.<sup>12,13</sup> LV fabricated using digital workflow have shown a satisfactory survival rate of 94% after 9 years.<sup>14</sup>

This article is protected by copyright. All rights reserved.

Various materials are used to fabricate chairside CAD-CAM veneers, such as glass ceramics (lithium disilicate, leucite-reinforced feldspathic, and feldspathic porcelain), zirconia, resin composite, resilient (hybrid) ceramics, polymer-infiltrated ceramics, and zirconia-reinforced lithium silicate (ZLS).<sup>15,16</sup> Dental glass-ceramics have become one of the first choice for clinicians because they provide excellent physical properties such as translucency, low thermal conductivity, adequate strength biocompatibility, wear resistance, and great esthetic results.<sup>17,18</sup> Companies continuously try to develop higher-strength glass ceramics by modifying the composition and simplifying the steps for fabrication and delivery.<sup>19,20</sup> A novel material is zirconia-reinforced lithium disilicate developed by Vita (Vita Zahnfabrik, Baden-Württemberg, Germany) and Dentsply (Dentsply Sirona, Charlotte, NC, USA) in conjunction with the Fraunhofer Institute for Silicate Research in Würzburg, Germany; they are separately marketed as two products: Vita Suprinity PC and Celtra Duo.<sup>21-23</sup> This novel material has a similar microstructure as traditional glass ceramics with lithium metasilicate crystallites ( $\text{Li}_2\text{Si}_2\text{O}_3$ ) and lithium orthophosphates crystallites ( $\text{Li}_3\text{PO}_4$ ). However, tetragonal zirconia fillers were added in order to increase the strength. A sintering process is provided so the crystals increase their size, and the lithium disilicate crystals ( $\text{Li}_2\text{Si}_2\text{O}_3$ ) are formed.<sup>24</sup> Several studies evaluating the properties and success of chairside CAD-CAM LV focus on lithium disilicate and feldspathic porcelain are available in current literature. However, research is lacking on recently developed materials.<sup>14,25</sup> In addition to the variety of material choice, tooth preparation with various incisal preparation designs is recommended for LV, including feathered-edge, butt-joint, and palatal chamfer (Fig 1).<sup>26</sup> Tooth preparation with feathered-edge preparation design avoid incisal overlap of LV on the incisal edge; however, LVs are overlapped on the incisal edge in butt-joint and palatal chamfer preparation designs.<sup>27,28</sup> The use of different preparation designs is based on the clinical experience and potential esthetic outcomes; however, there is no consensus on the impact of preparation design on the success and survival of the LV.<sup>29-32</sup>

The present comparative in-vitro study aimed to assess the fracture resistance of chairside LV manufactured from a recently developed ceramic (zirconia-reinforced lithium silicate) for tooth preparations with feathered-edge, butt-joint, and palatal chamfer designs. A full-coverage crown manufactured from the same material and fabrication technique was used as the control group. This study hypothesized that ‘there is no difference in fracture resistance among the three different preparation designs of LV’ and ‘complete coverage crowns have higher fracture resistance than tested LV.’

## Materials and Methods

The sample size for this study was calculated from a previous study<sup>33</sup> using G\*Power ( $\alpha = 0.05$ , power = 0.8). It was determined that 9–35 samples were needed for each group. Fifteen samples were used per group, similar to previous studies. Four maxillary right central incisors (1560 Series, Columbia Dentoform, Lancaster, PA, USA) were used to prepare teeth for (1) feathered-edge LV, (2) butt-joint LV, (3) palatal chamfer LV, and (4) complete coverage crown

(Fig. 1). Tooth preparations followed the manufacturer's recommendation for veneer with 0.4 mm chamfer, 0.6 facial reduction, and 1.0 mm incisal reduction. The full coverage crown was 1.0 mm chamfer with 1.5 mm facial reduction and 1.5 mm incisal reduction. The preparations were then digitally scanned using an intraoral scanner (Omnicam, Dentsply Sirona, Charlotte, NC, USA) to design LV and crowns following the anatomy of a preparation. Designed

restorations were then used to manufacture zirconia-reinforced lithium disilicate (Celtra Duo, Dentsply Sirona) restorations using a 5-axis milling machine (inLab MC-X5, Dentsply Sirona); 15 per group. Milled restorations were crystallized (Universal Spray Glaze Fluo, Dentsply Sirona, Charlotte, NC, USA) following the manufacturer's recommendations using a sintering oven (Programat CS2, Ivoclar Vivadent), and then the restorations were polished with a lithium disilicate polishing kit (Dialite LD, Brasseler USA, Savannah, GA, USA) following the manufacturers' recommendations. In addition, prepared typodont teeth were scanned using a desktop scanner (Freedom HD, DOF, Seoul, Korea), and virtual models were created a design software. STL files of virtual models were used to manufacture 60 dies using a 3D printer (Formlabs 3B, Formlabs Inc. Somerville, MA) from a resin for dental models (Model Resin, FormLabs, Somerville, MA, USA).

Restorations were ultrasonically cleaned in a bath (5300 Sweep Ultrasonic Cleaner, Quala Dental Products) with 90% isopropyl alcohol for 5 minutes. They were allowed to dry at room temperature; then, their intaglio surface was treated with 5% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent) for 30 seconds. Restorations were then rinsed with water spray and dried with an air syringe before the application of silane (Calibra Silane Coupling Agent, Dentsply Sirona) for 60 seconds. Restorations were then luted to their assigned 3D-printed teeth with resin cement (Calibra Ceram, Dentsply Sirona), following the manufacturer's instructions and using a light curing unit (Elipar 2500, 3M Oral Care, St Paul, MN, USA) with 200 g of applied weight. A single experienced prosthodontist performed all cementation procedures. After 48 hours, the specimens were subjected to artificial aging using a thermocycling machine (Thermo-cycler The-1100, SD Machatronik, Feldkirchen-Westerham, Germany) for 10,000 cycles between 5 °C and 55 °C with a dwell time of 30 seconds

This article is protected by copyright. All rights reserved.

(Figure 2). Specimens were then subjected to a compressive load at a crosshead of 1.0 mm/min until failure using a universal testing machine (858 Mini Bionix II, Eden Prairie, MN, USA). The fracture load was applied while specimens were mounted in a jig at a 40-degree inclination with a tapered cone-shaped indenter with 2.0 mm at the tip. The indenter centered on the lingual side of the sample was 2.0 mm from the incisal edge. A 1.5 mm thick piece of high-temperature silicone rubber was placed between the indenter and the veneer. The load at complete fracture was recorded in Newtons. A scanning electron microscope (TM3000 Hitachi, Tokyo, Japan) was used to perform a fractographic analysis of the broken specimens with an accelerating voltage of 5 kV. Individual images were stitched together using Affinity Designer (Serif Ltd., UK).

Fractographic analysis was assessed descriptively. A Kolmogorov-Smirnov test was used to assess the normal distribution of data. One-way ANOVA test and Bonferroni correction multiple comparisons were used to assess the impact of preparation design on the fracture strength of restorations at a significant level of 0.001.

## Results

### *Fracture Resistance*

The fracture strength of zirconia-reinforced lithium silicate restorations assessed in this study is shown in Table 1. The type of restoration influenced the fracture strength. The Kolmogorov-Smirnov test showed normal distribution of data. One-way ANOVA indicated a significant ( $p < 0.001$ ) effect of restoration type on fracture strength. Complete coverage crown displayed the highest fracture resistance ( $781.4 \pm 151.1$  N), followed by LV with palatal chamfer design ( $618.2 \pm 112.6$  N); however, the Bonferroni correction test showed that there was no significant difference between the groups ( $p = 0.449$ ). The fracture strength of LV with butt-joint design ( $385.2 \pm 119.7$  N) was significantly higher than LV with feathered-edge design ( $194.8 \pm 174.4$  N) ( $p < 0.001$ ); however, its fracture strength was significantly lower than LV with palatal chamfer design and complete coverage crown ( $p < 0.001$ ).

### *Fractographic Analysis*

Representative scanning electron microscopy (SEM) images of the fracture surfaces of zirconia-reinforced lithium silicate restorations are shown in Figures 3-6. The feathered-edge LV presented cracks on the sides of

the veneer (mesial and distal) and predominately failed due to adhesive failure, unlike all other groups. In contrast, the butt joint fractured along the incisal edge. Finally, palatal chamfer and full crowns presented similar fracture patterns to butt-joint, but full crown cracks were slightly smoother along the fractured surface.

## Discussion

Chairside CAD-CAM ceramic restorations have become very common in daily practice for their high accuracy, fast fabrication methods, and a wide variety of materials available.<sup>34,35</sup> This wide choice of materials enables LV to fulfill patients' esthetic demands.<sup>36,37</sup> LV can also be used to treat worn, malformed, fractured, and spaces between teeth (diastemas).<sup>38</sup> Clinicians have options with different preparation designs for ceramic LV, including feathered edge, butt joint (incisal bevel), and palatal chamfer (overlapped).<sup>39</sup> The present in vitro study included load-to-failure and fractographic failure analysis to compare the fracture resistance of feathered edge, butt joint, and palatal chamfer LV, as well as full crowns. Based on the results, the first null hypothesis was rejected because there were significant differences in the fracture resistance values among the groups. For instance, the butt joint LV with 385.2 ( $\pm 119.7$ ) N was significantly higher than the feathered edge LV with 194.9 ( $\pm 174.4$ ) N, whereas the palatal chamfer LV with 618.2 ( $\pm 112.6$ ) N was significantly higher than any other LV. Furthermore, the second hypothesis was "partially" rejected because there was one type of ZLS LV (palatal chamfer) that showed no significant difference compared to full-coverage crowns with 781.4 ( $\pm 151.1$ ) N.

The maxillary right central incisor was selected in this study because central incisors are the most noticeable teeth in the mouth and, therefore, can cause the most esthetic concerns addressed by clinicians.<sup>40</sup> However, anterior teeth are commonly treated with ceramic LV.<sup>41,42</sup> The restoration preparations followed the guidelines provided by Celtra Duo (Dentsply Sirona) for veneers: 1.5 mm incisal reduction, 0.4 mm incisal, and 0.6 middle third reduction, whereas for full-coverage crowns: 1.5 mm incisal reduction, 1.0 mm chamfer margin, and 1.5 mm middle third reduction.<sup>43</sup> According to the manufacturer, LV with ZLS can be fabricated with thicknesses from 1.0 to 1.5 mm. However, due to the standardization of this study, the authors decided to have it a 1.5 mm to match the full coverage crown recommendation.

The present study evaluated the most common LV preparations: feathered edge, butt joint, and palatal chamfer. The feathered edge LV only need to remove the unsupported enamel on the incisal edge and are widely

recommended for patients with stable occlusion and normal vertical overlap.<sup>44,45</sup> Butt joint LV only include the incisal overlap design and are indicated in patients with malocclusion such as anterior reverse articulation or excessive vertical overlap.<sup>46</sup> Palatal chamfer LV includes reduction and chamfer margin on the palatal surface and are indicated if the buccolingual incisal edge is thin or when the length of the restoration needs to be considerably increased.<sup>29,47</sup> Other types of veneer preparations have also been described, such as window preparation and ‘prepless veneers.’ However, the window preparation design is not a common treatment because it does not mask the ceramic finish line, causing chipping of unsupported enamel with compromised esthetics due to the partial coverage of facial surfaces.<sup>48-50</sup> Additionally, the ‘prepless veneer’ approach is still controversial because it lacks long-term clinical studies without clear protocols for finish design or margin, and laboratory fabrication is more complex than other types.<sup>51,52</sup> Therefore, those types of LV were not included in this study.

The results of this investigation showed the palatal chamfer veneers had the highest fracture resistance across veneer preparations. These results agreed with previous studies using different ceramics and methodologies. Another in-vitro study compared the fracture resistance of LV with no incisal reduction with bucco-incisal bevel, 1 mm incisal reduction with butt joint, and a 1 mm incisal reduction with 1 mm height of palatal chamfer LV fabricated with porcelain ceramic.<sup>53</sup> They found that palatal chamfer veneers bonded to natural teeth showed the highest value.<sup>53</sup>

Another study comparing pressable lithium disilicate ceramic for LV with incisal shoulder finish line with and without palatal chamfer cemented to natural teeth concluded that using the palatal chamfer design significantly increased the fatigue failure cycle count.<sup>54</sup> Moreover, a 3-dimensional finite element study comparing maxillary incisors restored with a butt joint and palatal chamfer ceramic LV demonstrated different mechanic behaviors.<sup>55</sup> It concluded that incisal overlap design with palatal chamfer tolerated stress better.<sup>55</sup> To the best of the authors’ knowledge, this is the first study that evaluates different veneer designs with the ZLS ceramic. Full coverage crowns displayed the highest fracture resistance ( $781.4 \pm 151.1$  N); this may be due to the ceramic veneer with Celtra Duo being thinner on the facial surface with 0.6 mm in middle-third and 0.4 mm at the chamfer while the full coverage crown is 1.5 mm at the middle third and 1.0 mm at the chamfer margin. This result concurs with other studies showing that the thicker the ceramic restoration the higher fracture resistance is displayed.<sup>33,56</sup>

Further studies should evaluate the fracture resistance of other teeth restored with LV, especially the canines. A limitation of this study was using printed resin dies instead of natural teeth, but resin dies have been utilized

This article is protected by copyright. All rights reserved.



in previously published studies, providing reliable results. Furthermore, the resin dies decrease the variability and

challenges caused by natural teeth, such as collecting natural anterior teeth without caries, performing similar hand-prepping LV and crown preparations, and storing natural teeth. In addition, longer aging and fatigue cycling may also provide better performance evaluation for the restorations. More detailed fractography would contribute to a more precise determination of failure modes. Another limitation of this study is using only one type of novel ceramic (zirconia-reinforced lithium disilicate). The market offers other novel ceramics, such as polymer-infiltrated ceramics, so future studies should also compare more novel CAD-CAM dental ceramics. Lastly, this study only evaluated maxillary central incisor veneers. This is a limitation because other anterior teeth, such as canines, should be evaluated to obtain broader data on the behavior of this novel ceramic in anterior teeth.

### **Conclusion**

The incisal edge design influences the fracture resistance of chairside CAD-CAM ZLS LV. Palatal chamfer veneers provided higher fracture strength than butt joint veneers, and feathered edge veneers displayed the lowest values. Palatal chamfer veneers displayed no statistically significant difference compared to veneers with a palatal chamfer in fracture strength.

## References

1. Mörmann WH. The evolution of the CEREC system. *J Am Dent Assoc* 2006;137: 7S–13S
2. Jurado CA, Lederman R, Cohen J, Tsujimoto A. Intraoral Scanning with Rubber Dam Isolation in Place for Fabrication of a Chairside Computer-assisted Design and Computer-assisted Manufacture Ceramic Restoration. *J Contemp Dent Pract.* 2021 Aug 1;22(8):943-946.
3. Hashemi AM, Hashemi HM, Siadat H, Shamshiri A, Afrashtehfar KI, Alikhasi M. Fully Digital versus Conventional Workflows for Fabricating Posterior Three-Unit Implant-Supported Reconstructions: A Prospective Crossover Clinical Trial. *Int J Environ Res Public Health.* 2022 Sep 12;19(18):11456. doi: 10.3390/ijerph191811456.
4. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM Ceramic Restorative Materials for Natural Teeth. *J Dent Res.* 2018 Sep;97(10):1082-1091. doi: 10.1177/0022034518779759. Epub 2018 Jun 15.
5. Jurado CA, Tsujimoto A, Punj A, Aida N, Miyazaki M, Watanabe H. Successful development and implementation of a digital dentistry curriculum at a US dental school. *J Oral Sci.* 2021 Oct 1;63(4):358-360. doi: 10.2334/josnusd.21-0070. Epub 2021 Sep 9.
6. Dano D, Stiteler M, Giordano R. Prosthetically Driven Computer-Guided Implant Placement and Restoration Using CEREC: A Case Report. *Compend Contin Educ Dent.* 2018 May;39(5):311-317.
7. Jurado CA, Tsujimoto A, Watanabe H, Villalobos-Tinoco J, Garaicoa JL, Markham MD, Barkmeier WW, Latta MA. Chair-side CAD/CAM fabrication of a single-retainer resin bonded fixed dental prosthesis: a case report. *Restor Dent Endod.* 2020 Feb 6;45(2):e15. doi: 10.5395/rde.2020.45.e15.

8. Hasanzade M, Aminikhah M, Afrashtehfar KI, Alikhasi M. Marginal and internal adaptation of single crowns and fixed dental prostheses by using digital and conventional workflows: A systematic review and meta-analysis. *J Prosthet Dent*. 2021 Sep;126(3):360-368. doi: 10.1016/j.prosdent.2020.07.007. Epub 2020 Sep 12.
9. Hasanzade M, Shirani M, Afrashtehfar KI, Naseri P, Alikhasi M. In Vivo and In Vitro Comparison of Internal and Marginal Fit of Digital and Conventional Impressions for Full-Coverage Fixed Restorations: A Systematic Review and Meta-analysis. *J Evid Based Dent Pract*. 2019 Sep;19(3):236-254. doi: 10.1016/j.jebdp.2019.04.003. Epub 2019 Apr 25.
10. Bayazit EÖ, Karabıyık M. Chairside Restorations of Maxillary Anterior Teeth with CAD/CAM Porcelain Laminate Veneers Produced by Digital Workflow: A Case Report with a Step to Facilitate Restoration Design. *Case Rep Dent*. 2019 Apr 4;2019:6731905. doi: 10.1155/2019/6731905.
11. Jurado CA, Mourad F, Felton D, Tinoco JV. Clinical workflow of two different CAD/CAM systems for veneers manufacture. *Eur J Gen Dent* 2020;9:174-80.
12. Seydler B, Schmitter M. Esthetic restoration of maxillary incisors using CAD/CAM chairside technology--a case report. *Quintessence Int*. 2011 Jul-Aug;42(7):533-7.
13. Schmitter M, Seydler B B. Minimally invasive lithium disilicate ceramic veneers fabricated using chairside CAD/CAM: a clinical report. *J Prosthet Dent*. 2012 Feb;107(2):71-4. doi: 10.1016/S0022-3913(12)00012-1.
14. Wiedhahn K, Kerschbaum T, Fasbinder DF. Clinical long-term results with 617 Cerec veneers: a nine-year report. *Int J Comput Dent*. 2005 Jul;8(3):233-46. English, German.
15. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM Ceramic Restorative Materials for Natural Teeth. *J Dent Res*. 2018 Sep;97(10):1082-1091. doi: 10.1177/0022034518779759. Epub 2018 Jun 15.

16. Marchesi, G.; Camurri Piloni, A.; Nicolin, V.; Turco, G.; Di Lenarda, R. Chairside CAD/CAM Materials: Current Trends of Clinical Uses. *Biology* 2021, 10, 1170.
17. Fu L, Engqvist H, Xia W. Glass-Ceramics in Dentistry: A Review. *Materials* (Basel). 2020 Feb 26;13(5):1049. doi: 10.3390/ma13051049. PMID: 32110874; PMCID: PMC7084775.
18. Diken Türksayar AA, Demirel M, Donmez MB. Optical properties, biaxial flexural strength, and reliability of new-generation lithium disilicate glass-ceramics after thermal cycling. *J Prosthodont*. 2022 Dec 30. doi: 10.1111/jopr.13632. Epub ahead of print. PMID: 36585789.
19. Rekow, E.D.; Silva, N.R.F.A.; Coelho, P.G.; Zhang, Y.; Guess, P.; Thompson, V.P. Performance of dental ceramics: Challenges for improvements. *J. Dent. Res.* 2011, 90, 937–952.
20. Phark JH, Duarte S Jr. Microstructural considerations for novel lithium disilicate glass ceramics: A review. *J Esthet Restor Dent*. 2022 Jan;34(1):92-103. doi: 10.1111/jerd.12864. Epub 2022 Jan 7. PMID: 34995008
21. Celtra Duo. Zirconia-Reinforced Lithium Silicate (ZLS) Block. Technical Monograph. Dentsply Sirona IC., DeguDent GmbH, Hanau, Wolfgang, Germany. 2016. <https://www.dentsplysirona.com/en-us/discover/discover-by-brand/celtra-duo.html>
22. Riquieri H, Monteiro JB, Viegas DC, Campos TMB, de Melo RM, de Siqueira Ferreira Anzaloni Saavedra G. Impact of crystallization firing process on the microstructure and flexural strength of zirconia-reinforced lithium silicate glass-ceramics. *Dent Mater*. 2018 Oct;34(10):1483-1491. doi: 10.1016/j.dental.2018.06.010. Epub 2018 Jun 23. PMID: 29945797
23. Vita Suprinity PC. Technical and Scientific Documentation. Vita Zahnfabrik, Bad Sackingen, Germany (2019) (Accessed January 2023) <http://www2.vitanorthamerica.com/products/cadcam/vita-suprinity/>
24. Belli R, Wendler M, de Ligny D, Cicconi MR, Petschelt A, Peterlik H, Lohbauer U. Chairside CAD/CAM materials. Part 1: Measurement of elastic constants and microstructural characterization. *Dent Mater*. 2017 Jan;33(1):84-98. doi: 10.1016/j.dental.2016.10.009. Epub 2016 Nov 24. PMID: 27890354.

25. Baroudi K, Ibraheem SN. Assessment of Chair-side Computer-Aided Design and Computer-Aided Manufacturing Restorations: A Review of the Literature. *J Int Oral Health*. 2015 Apr;7(4):96-104.
26. Da CD, Coutinho M, de Sousa AS, & Ennes JP (2013) A meta-analysis of the most indicated preparation design for porcelain laminate veneers *Journal of Adhesive Dentistry* 15(3) 215-220.
27. Clyde JS, Gilmour A. Porcelain veneers: a preliminary review. *Br Dent J*. 1988;164(1):9-14.
28. Walls AW, Steele JG, Wassell RW. Crowns and other extra-coronal restorations: porcelain laminate veneers. *Br Dent J*. 2002;193(2):73-76, 79-82.
- 29.. Garber D. Porcelain laminate veneers: ten years later, part I-Tooth preparation. *J Esthet Dent*. 1993;5(2): 56-62.
30. Gilmour AS, Stone DC. Porcelain laminate veneers: a clinical success? *Dent Update*. 1993;20(4): 167-169, 171-173.
31. Smales RJ, Etemadi S. Long-term survival of porcelain laminate veneers using two preparation designs: a retrospective study. *Int J Prosthodont*. 2004;17(3): 323-326
32. Cötert HS, Dündar M, Oztürk B. The effect of various preparation designs on the survival of porcelain laminate veneers. *J Adhes Dent*. 2009;11(5):405-411.
33. Jurado CA, Pinedo F, Trevino DAC, Williams Q, Marquez-Conde A, Irie M, Tsujimoto A. CAD/CAM lithium disilicate ceramic crowns: Effect of occlusal thickness on fracture resistance and fractographic analysis. *Dent Mater* J. 2022 Oct 2;41(5):705-709. doi: 10.4012/dmj.2022-018. Epub 2022 Jul 6.

34. Ahrberg D, Lauer HC, Ahrberg M, Weigl P. Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: a double-blinded, randomized clinical trial. *Clin Oral Investig*. 2016 Mar;20(2):291-300. doi: 10.1007/s00784-015-1504-6. Epub 2015 Jun 14.
35. Dickens N, Haider H, Lien W, Simecek J, Stahl J. Longitudinal Analysis of CAD/CAM Restoration Incorporation Rates into Navy Dentistry. *Mil Med*. 2019 May 1;184(5-6):e365-e372. doi: 10.1093/milmed/usy260.
36. Alikhasi M, Yousefi P, Afrashtehfar KI. Smile Design: Mechanical Considerations. *Dent Clin North Am*. 2022 Jul;66(3):477-487. doi: 10.1016/j.cden.2022.02.008. Epub 2022 May 31.
37. Guichet DL. Digital Workflows in the Management of the Esthetically Discriminating Patient. *Dent Clin North Am*. 2019 Apr;63(2):331-344. doi: 10.1016/j.cden.2018.11.011. Epub 2019 Feb 2.
38. Shi S, Li N, Jin X, Huang S, Ma J. A Digital Esthetic Rehabilitation of a Patient with Dentinogenesis Imperfecta Type II: A Clinical Report. *J Prosthodont*. 2020 Oct;29(8):643-650. doi: 10.1111/jopr.13237. Epub 2020 Sep 10.
39. Vasques WF, Sá TA, Martins FV, Fonseca EM. Composite resin CAD-CAM restorations for a midline diastema closure: A clinical report. *J Prosthet Dent*. 2022 Feb;127(2):206-209. doi: 10.1016/j.prosdent.2020.07.022. Epub 2020 Nov 25.
40. Machado AW. 10 commandments of smile esthetics. *Dental Press J Orthod*. 2014 July-Aug;19(4):136-57. DOI: <http://dx.doi.org/10.1590/2176-9451.19.4.136-157.sar>

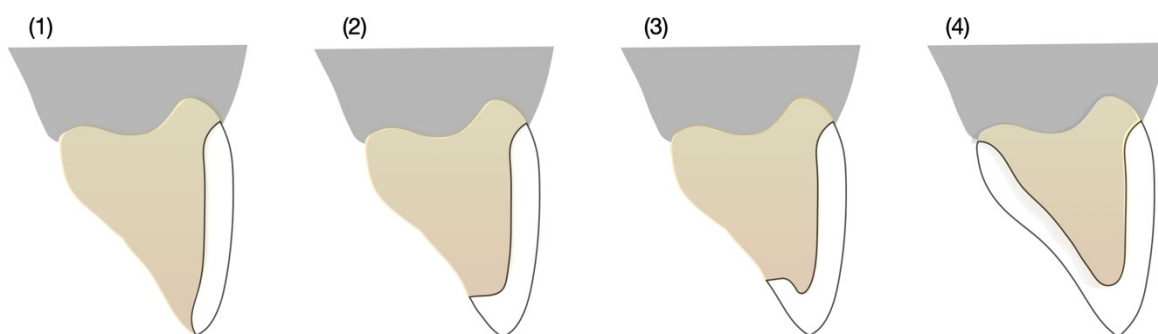
41. Villalobos-Tinoco J, Jurado CA, Rojas-Rueda S, Fischer NG. Additive Wax-Up and Diagnostic Mockup As Driving Tools for Minimally Invasive Veneer Preparations. *Cureus*. 2022 Jul 28;14(7):e27402. doi: 10.7759/cureus.27402.
42. Magne P, Hanna J, Magne M. The case for moderate "guided prep" indirect porcelain veneers in the anterior dentition. The pendulum of porcelain veneer preparations: from almost no-prep to over-prep to no-prep. *Eur J Esthet Dent*. 2013 Autumn;8(3):376-88.
43. Celtra Duo. Zirconia-reinforced lithium disilicate (ZLS). Guidelines for processing Celtra Duo. Dentsply Sirona. <https://www.dentsplysirona.com/en-us/discover/discover-by-brand/celtra-duo.html>
44. Nordbø H, Rygh-Thoresen N, Henaug T. Clinical performance of porcelain laminate veneers without incisal overlapping: 3-year results. *J Dent*. 1994;22(6):342-345.
45. Boksman L, Jordan RE, Suzuki M, Galil KA, Burgoyne AR. Etched porcelain labial veneers. *Ont Dent*. 1985;62(1):11, 13, 15-19
46. Calamia JR. Materials and technique for etched porcelain facial veneers. *Alpha Omegan*. 1988;81(4): 48-51.
47. Garber DA. Rational tooth preparation for porcelain laminate veneers. *Compendium*. 1991;12(5):316, 318, 320.
48. Walls AW, Steele JG, Wassell RW. Crowns and other extra-coronal restorations: porcelain laminate veneers. *Br Dent J*. 2002;193(2):73-76, 79-82.
49. Brunton PA, Wilson NH. Preparations for porcelain laminate veneers in general dental practice. *Br Dent J*. 1998;184(11):553-556.
50. Clyde JS, Gilmour A. Porcelain veneers: a preliminary review. *Br Dent J*. 1988;164(1):9-14.
51. Romeo G, Iliev G. Non-prep veneer technique: an analytical laboratory model approach. *Int J Esthet Dent*. 2022 May 25;(2):152-161.

52. D'Arcangelo C, Vadini M, D'Amario M, Chiavaroli Z, De Angelis F. Protocol for a new concept of no-prep ultrathin ceramic veneers. *J Esthet Restor Dent*. 2018 May;30(3):173-179. doi: 10.1111/jerd.12351. Epub 2017 Nov 15.
53. Jankar AS, Kale Y, Kangane S, Ambekar A, Sinha M, Chaware S. Comparative evaluation of fracture resistance of ceramic veneer with three different incisal design preparations: an in-vitro study. *J Int Oral Health*. 2014;6(1):48-54.
54. Chaiyabutr Y, Phillips KM, Ma PS, Chitswe K. Comparison of load-fatigue testing of ceramic veneers with two different preparation designs. *Int J Prosthodont*. 2009 Nov-Dec;22(6):573-5.
55. Li Z, Yang Z, Zuo L, Meng Y. A three-dimensional finite element study on anterior laminate veneers with different incisal preparations. *J Prosthet Dent*. 2014 Aug;112(2):325-33. doi: 10.1016/j.prosdent.2013.09.023. Epub 2014 Feb 8.
56. Jasim HH, Findakly MB, Mahdi NA, Mutar MT. Effect of Reduced Occlusal Thickness with Two Margin Designs on Fracture Resistance of Monolithic Zirconia Crowns. *Eur J Dent*. 2020 Mar;14(2):245-249. doi: 10.1055/s-0040-1709342. Epub 2020 Jun 5. PMID: 32503065; PMCID: PMC7274823.

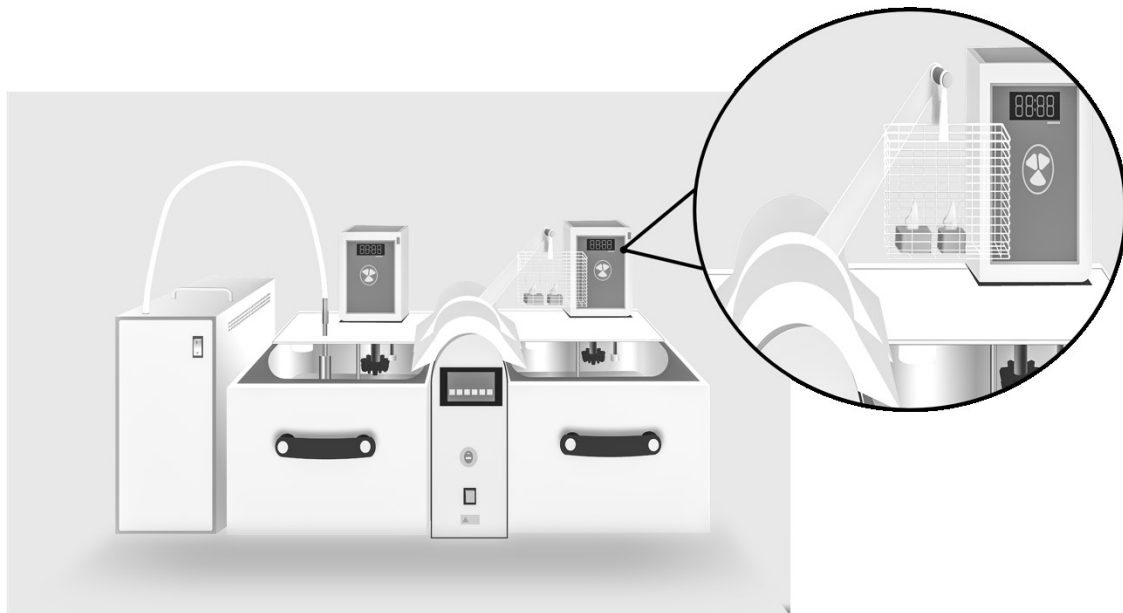


Figures

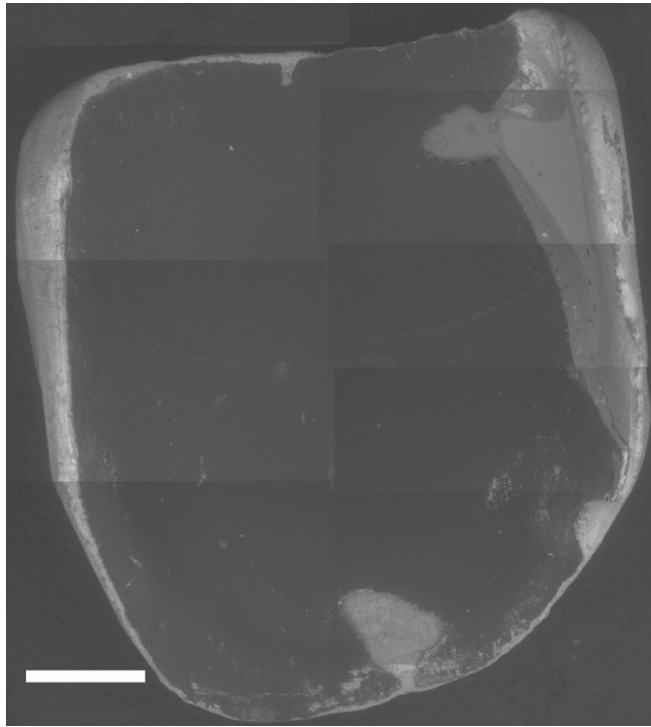
**Figure 1.** Schematic drawing of the four types of restorations prepared. (1) Veneers with feathered edge; (2) Veneers with butt joint; (3) Veneers with palatal chamfer; and (4) Full-coverage single crowns.



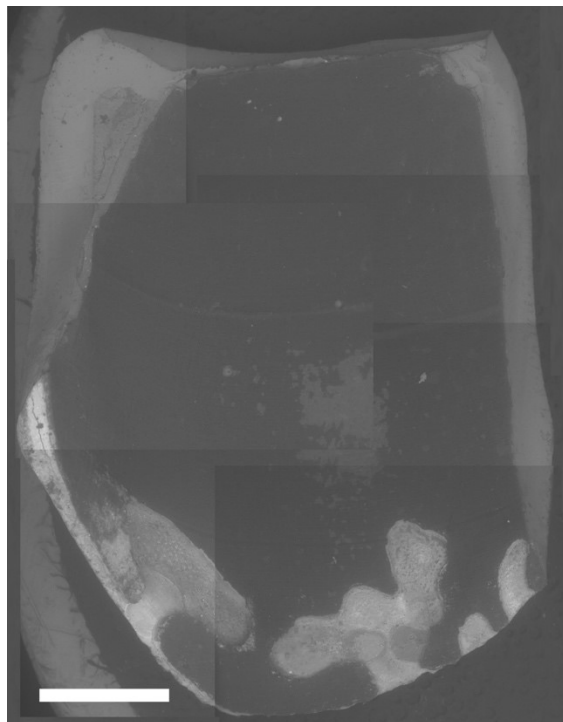
**Figure 2.** The bonded restorations were subjected to 10,000 thermocycles at 5 °C to 55 °C with a dwell time of 30 seconds.



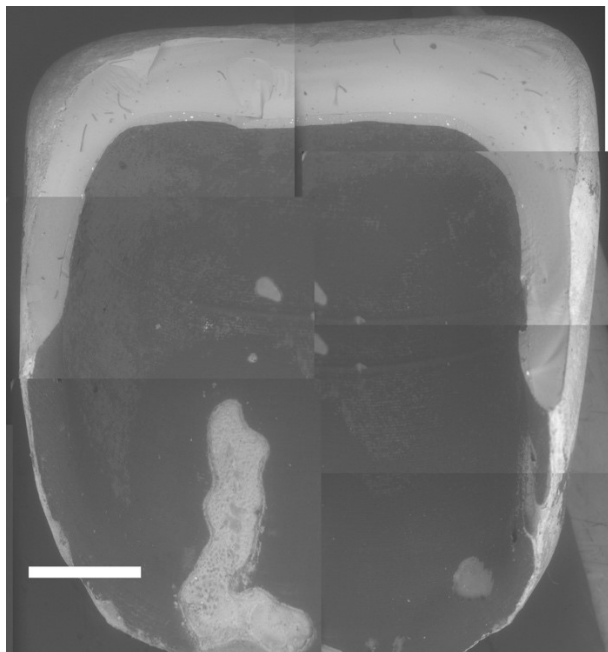
**Figure 3.** SEM image of a fractured veneer with feathered edge. Feathered-edge LV presented cracks on the sides of the veneer (mesial and distal) and predominately failed due to adhesive failure. Scale bar is 2 mm.



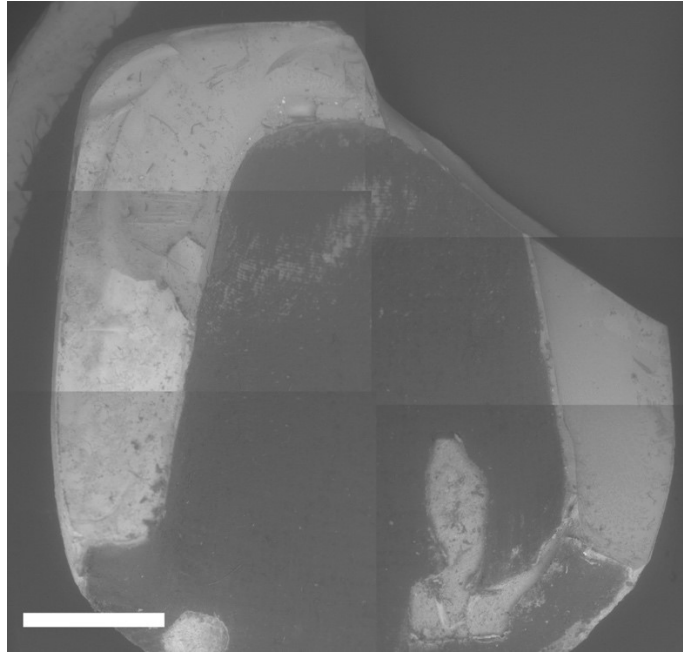
**Figure 4.** SEM image of fractured veneer with butt joint. Butt-joint LV fractured along the incisal edge. Scale bar is 2 mm.



**Figure 5.** SEM image of a fractured veneer with palatal chamfer. Palatal chamfer LVs fractured along the incisal edge. Scale bar is 2 mm.



**Figure 6.** SEM image of a fractured traditional crown. Traditional crowns fractured along the incisal edge with smoother cracks than other groups along the fractures surface. Scale bar is 2mm.



## Tables

**Table 1.** Fracture strength of zirconia-reinforced lithium silicate restorations.

Type of Restoration	Mean $\pm$ SD (N)
Feathered-Edge Laminate Veneer	194.9 $\pm$ 174.4 <sup>a</sup>
Butt-Joint Laminate Veneer	385.2 $\pm$ 119.7 <sup>b</sup>
Palatal Chamfer Laminate Veneer	618.2 $\pm$ 112.6 <sup>c</sup>
Complete Coverage Single Crown	781.4 $\pm$ 151.1 <sup>c</sup>

The same superscript letter in the right column indicates no significant difference ( $p < 0.001$ ).

Abbreviation: SD, standard deviation.