Accuracy Comparison of Different Chairside Retrofitting CAD/CAM Ceramic Inlays to An Existing Removable Partial Denture

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Abstract

The accuracy of three distinct chairside retrofitting CAD/CAM ceramic inlays on the four different areas of an existing RPD rest was compared. Three types of ceramics were used in the experiment: hybrid ceramics (HC, n=10), lithium disilicate ceramics (LDSC, n=10), and zirconia-reinforced lithium silicate ceramics (ZLSC, n=10). The control group used direct composite filling (C, n=10). The program was used to measure the space between the rest seat and the retrofitting ceramic inlay, using a silicone replica as a representation. Two-way ANOVA and Tukey's multiple comparison test (α=0.05) were the statistical tests used. HC, LDSC, and ZLSC, display the approximate gaps at all cavosurface areas (143-149, 145-153, and 151-155 µm, respectively, P>.05), whereas the smallest gap was seen at the deepest area (6, 25, and 34 µm, respectively, P<.05). In conclusion, there are differences in the accuracy of retrofitting rest seats under existing RPD rests in different materials and areas. The milling area has an impact on the accuracy of retrofitting restoration between RPD rest and CAD/CAM ceramic rest seats. The accuracy of retrofitting restoration can be affected by the type of ceramics and their processing conditions, especially in the deepest area.

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Introduction

Patients frequently report with dental cavities or dislodged fillings under an existing removable partial denture (RPD) during the maintenance phase of the device[1, 2]. Selecting the proper material that offers strength, fracture resistance, and durability to withstand occlusal loading is essential for successful restorative repair under the current RPD. Complete seating is also necessary for the new renovation. Inaccurate seating results in pain in the gingiva, edentulous region, and teeth, as well as tooth mobility and a tilted denture[1]. It has been suggested recently to use computer-aided design and computer-aided manufacture (CAD/CAM) to create a restoration that fits properly[3, 4]. Chairside CAD/CAM ceramic restorations could meet this need because patients could tolerate dental treatment for a short four- to six-hour duration since they may be completed in one visit. The combined amount of time needed for sintering and milling is between 10 to 60 minutes[5, 6, 7]. The development of CAD/CAM ceramic materials has enabled chemical stability, wear resistance, and esthetic requirements[3, 4, 8, 9, 10]. Thus, zirconia-reinforced lithium silicate glass ceramics (ZLSC), lithium disilicated glass ceramics (LDSC), and hybrid ceramics (HC) were equally intriguing. As stated above, the purpose of this in *vitro* study is to assess the accuracy of several chairside CAD/CAM ceramic inlays (HC, LDSC, and ZLSC) for retrofitting to the various regions of the current RPD rest.

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Materials and methods

1. *Jigsaw-Like Mold Preparation*

The exterior frame mold was fabricated using stainless steel (16x24x20 mm.). There was an internal space (8x13x3 mm), along with 3 indentation lines and 2 half-circle slots (3 mm. in diameter). Three indentation lines represent the different areas of the RPD rest: 1) the cavosurface area of the terminus, 2) the deepest point, and 3) the proximal cavosurface areas (right and left), respectively (Figure 1A). Parts 1 and 2 made up the interior jigsaw-like mold. Part 1 simulates the retrofitting restoration space. Part 2 consists of 1 rest and 2 extension slots, using cast Co-Cr alloy to imitate the RPD rest of the mandibular first premolar. A knob for managing and positioning a load is located on top (Figure 1B).

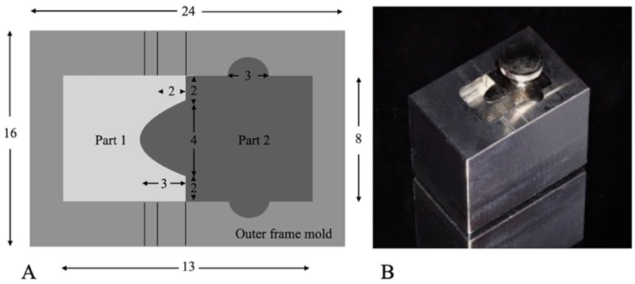

Figure 1. The preparation of a jigsaw-like mold. A. The outer frame mold comes with an inner part 1 and part 2, which are measured in millimeters. B. Part 1 is the space for retrofitting restoration, while part 2 is cast using Co-Cr alloy and fits precisely with the knop on top for handing and loading.

2. Experimental Group Specimen Preparation: CAD/CAM Ceramics

Part 1 space was filled with an addition silicone (Occlufast Rock, Zhermack, Badia Polesine, Italy). Then, part 2 was loaded (1 kg) and waited until complete polymerization. Next, the excess was trimmed with a scalpel, resulting in the silicone pattern of the inlay (Figure 2A). After that, it was scanned by the intra-oral scanner (Trios 4; 3Shape, Copenhagen, Denmark). The scanned data was sent to the CAD software program (Dental System 2014; 3Shape, Copenhagen, Denmark) and a 4-axis milling machine (DGShape DWX-42W, Roland DG Corporation, Japan). Three groups of ceramic blocks were milled using different materials: HC (Vita Enamic®, VITA, Germany), LDSC (IPS E.max CAD, Ivoclar Vivadent, Liechtenstein), and ZLSC (Vita Suprinity, Vita Zahnfabrick, Bad Säckingen, Germany)[5,6,7]. Then, the LDSC and ZLSC groups were sintered according to their manufacturing instructions (Figure 2B)[6,7]. Finally, specimens of each group were kept in a dry box at room temperature (n = 10).

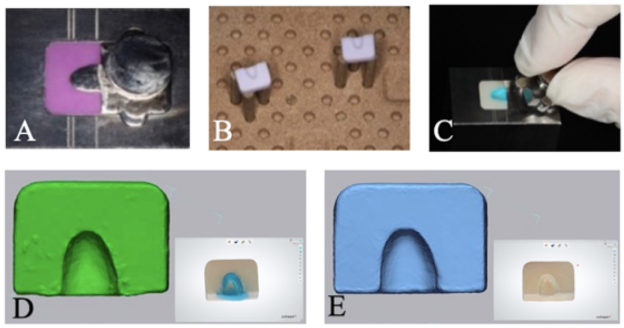

Figure 2. A. A silicone pattern of the inlay was created in part 1. B. Ceramic specimens were sintered, using LDSC and ZLSC. C. The silicone replica was attached to part 1. D. Data 1 was obtained by scanning the ceramic specimen attached to the silicone replica. E. Data 0 was obtained by scanning the ceramic specimen without the silicone replica.

3. Control Group Specimen Preparation: Resin Composite

Part 1 space was filled with bulk-fill resin composite (Filtek Bulk-Fill; 3M ESPE, Saint Paul, MN, USA). Then, part 2 was loaded (1 kg) by a specimen positioner jig (S4660A, Instron, Norwood, Massachusetts, USA). After that, light curing was performed by LED light (Mini LEDTM Standard F, ACTEON, Norwich, UK) for 20 seconds (1,250 mW/cm2 and 420–480 nm). Finally, they were kept in a dry box at room temperature (n = 10).

4. Gap Measurement

Gap measurement was performed according to earlier studies[2, 11, 12, 13]. The light body addition silicone impression material (Aquasil Ultra Plus LV® Impression Material; Dentsply Sirona, York, USA) was used to check the fit accuracy. The thickness of the silicone material refers to the gap between the specimen and part 2. Firstly, the specimen was inserted into the space of the exterior frame mold. Then the silicone was injected into the rest seat area. After that, part 2 was placed and loaded (1kg) for 5 minutes for complete polymerization. Then part 2 was removed, resulting in silicone remaining in the specimen (Figure 2C). Next, the specimen with the attached silicone replica was scanned by an intra-oral scanner (Trios 4; 3Shape, Copenhagen, Denmark), resulting in “data 1” (Figure 2D). Then, the replica was removed, and the specimen was scanned in the same manner, resulting in “data 0” (Figure 2D). Next, they were superimposed with best fit matching, representing the thickness of the silicone replica. Using the software's virtual cross-sectioning feature, the measurement was taken on each specimen at four different points, A represents the deepest area, B represents the terminus area, C represents the left proximal cavosurface area, and D represents the right proximal cavosurface area (Geomagic Control X version 2022.0.1.40, 3D Systems, Rock Hill, SC, USA). The 0.4 mm-diameter virtual circle was created at points A, B, C, and D. The three random measurements were used to average the representative gap value for each site (Figure 3).

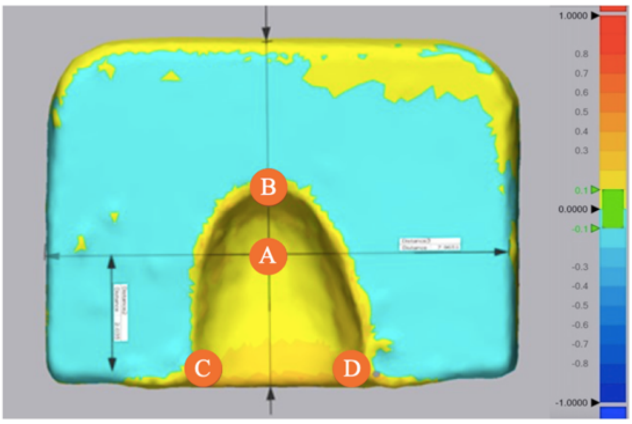

Figure 3. The superimposition of Data 1 and Data 0 has been completed. The measurement was conducted at 4 points (A, B, C, and D) on each specimen using the virtual cross-sectioning feature of the software (Geomagic Control X version 2022.0.1.40, 3D Systems, Rock Hill, SC, USA). The color bar on the right shows the gap size in millimeters. A represents the deepest area, B represents the terminus area, C represents the left proximal cavosurface area, and D represents the right proximal cavosurface area.

5. Statistical Test

Using two-way ANOVA and Tukey's test at a significance level of 0.05, the gap size of the retrofitting rest seat under the existing RPD rest in various materials and areas was compared (IBM SPSS Statistics for Windows, Version 25.0; Armonk, NY: IBM Corp.).

Results

The accuracy was significantly impacted by various materials and areas of rest seat (P<0.05). The gap size is depicted in Figure 4 and can be explained as follows: At points B, C, and D, the three ceramic groups (HC, LDSC, and ZLSC) displayed identical gap sizes (varying from 143-155 μm), P>.05. They demonstrated that, in comparison to points B, C, and D, point A had the smallest gap size (P<.05). Among the three ceramic groups at point A, the gap size of HC was the smallest at 6 μm (P=.006). In addition, at point A, the ceramic groups, ZLSC and LDSC, had the same gap size (P>.05). Moreover, the ceramic group, at point A, HC (6 μm) and LDSC (25 μm), showed a smaller gap size than that of the control group (45 μm), P<.05. The control group or direct filling of resin composite showed the same gap size at all sites (A = 45 μm, B = 49 μm, C = 58 μm, and D = 59 μm), P>.05.

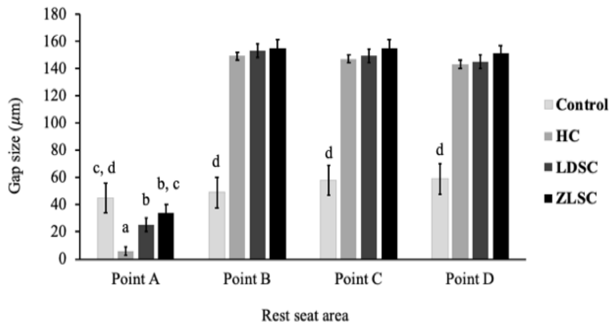

Figure 4. The gap size between retrofitting rest seat and existing RPD rest of different materials and different areas (mean ± SD). HC = hybrid ceramics, LDSC = lithium disilicate, ZLSC = zirconia-reinforced lithium silicate, and Control = bulk-fill resin composite. Point A represents the deepest area, B represents the terminus area, C represents the left proximal cavosurface area, and D represents the right proximal cavosurface area. Different lowercase letters (a, b, c, and d) indicate a statistically significant difference (P<.05), n=10.

Discussion

This study investigated accuracy in fabricating chairside retrofitting CAD/CAM ceramic inlay rest seats to the existing RPD. HC, LDSC, and ZLSC showed the same gap size at points B, C, and D (ranging from 143-155 μm), p>0.05. In addition, HC, LDSC, and ZLSC showed the smallest gap size at point A (6, 25, and 34 µm, respectively) as compared to that of points B, C, and D (*P*<0.05). These results indicate that the area of milling affected the accuracy of the CAD/CAM ceramic rest seat to the existing RPD rest. The deepest area revealed a smaller gap than that of the other three areas. It is possible that the deepest area may be undermilled, resulting in impeding the intimate contact of the other 3 areas. The non-homogeneous gap size was described by some authors as commonly occurring in CAD/CAM technology. This may be related to the quality of processing of the digital data, the diameter and shape, and the limited ability of milling instruments[15, 16].

However, all the areas display an acceptable gap size, according to the earlier study of the gap size between the surveyed crown and RPD. They clarified that gaps between 50 and 311 µm are categorized as "acceptable," whereas gaps smaller than 50 µm are categorized as "no gap"[17]. Consequently, it is possible to precisely mill HC, LDSC, and ZLSC in order to complete the retrofitting restoration.

At point A, the ceramic group, HC had the smallest gap size as compared to the other 2 ceramic groups (*P*=.006). This result indicates that the type of ceramics affects the accuracy between rest and ceramic rest seat at the deepest area. This may be caused by the shrinkage of pre-crystallized LDSC and ZLSC that occurred after post-milling sintering at 840˚C for 18.27 and 20 minutes, respectively, while HC does not need that process, according to the manufacturer's instruction. This agrees with previous studies revealed that the marginal gap of LDS crown increased after post-milling sintering[18,19,20]. The crystal spacing became denser and shrinkable during crystallization[16]. In addition, some authors found that crowns made from HC exhibited more fitness than those of LDSC and ZLSC[14].

At point A, ZLSC and LDSC had the same gap size (*P*>.05). The fitness of crowns made from LDSC and ZLSC did not differ noticeably, likely due to their similar chemical compositions. However, HC has a distinct composition compared to LDSC and ZLSC. As a result, the accuracy of retrofitting restorations can be affected by the type of ceramics and the methods used for processing. At point A, the ceramic group, HC and LDS, showed a smaller gap size of 6 µm and 25 µm respectively, compared to the control group with a gap size of 45 µm, *P*<.05. This difference might be due to the different techniques used in making the restorations. The ceramic group was made using the indirect milling technique, while the control group was done through the direct technique of resin composite filling. Türk et al (2016) discovered a smaller marginal discrepancy of the direct technique composite inlay (56.88-91.88 µm) in contrast with the indirect technique (107.54-170.29 µm)[21]. This finding is consistent with the present study. The result indicates that the indirect milling technique provides a smaller gap size (6-25 µm) in the deepest area compared to the direct composite filling technique (45 µm). This could be due to undermilling and shrinkage during sintering of ceramics as explained earlier. However, the final gap size in both ceramic groups and the resin composite group is still within an acceptable range.

This in vitro study suggests that HC, LDSC, and ZLSC could be used as a retrofitting inlay restoration. The CAD software ability could compensate for the ceramic shrinkage and the high-quality milling instruments result in acceptable accuracy. Even though, there is some non-uniform adaptation, especially in the deepest area of rest related to the limitation of the 4-axis milling machine in this study. Hence, the point stress concentration may affect the deepest area of restoration after applying occlusal load, resulting in fracture failure. The precision of a 5-axis milling machine was presented by many studies[20,22,23]. Interestingly, the chairside 5-axis milling machine may provide a more homogeneous gap size than that of the 4-axis one and reduce the risk of fracture failure at the deepest area. However, the overall gap size in all areas by the 4-axis milling machine utilized in this study is still within acceptable limits. The study was limited to simple laboratory geometry and may not reflect clinical conditions, as retrofitting restorations in clinical conditions can have more complex geometry such as onlays and crowns.

Conclusions

There are differences in the accuracy of retrofitting rest seats under existing RPD rests in different materials and areas. The following points explain these differences:

1) The milling area has an impact on the accuracy of retrofitting restoration between RPD rest and indirect CAD/CAM ceramic rest seats.

2) The accuracy of retrofitting restoration can be affected by the type of CAD/CAM ceramics and their processing conditions, especially in the deepest area.

3) The gap size of CAD/CAM ceramics (HC, LDSC, and ZLSC) is acceptable for retrofitting RPD (6-155 µm).

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Declaration of Interest

The authors report no conflict of interest.

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