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Effect of Core Thickness and Porcelain Sintering on Marginal

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ABSTRACT

Background and aim: Marginal adaptation affects the long-term success of full-coverage restorations. This study aimed to assess the effect of porcelain sintering and zirconia core thickness on the marginal adaptation of all-ceramic restorations.

Materials and methods: In this in-vitro experimental study, a standard brass die, 7 mm in length and 5 mm in diameter, was fabricated using a milling machine. A classic chamfer finish line with the depth of 0.8 mm was prepared with 10-degree tapered walls. Copings were fabricated on the die using the computer aided design/computer aided manufacturing (CAD/CAM) system and were divided into three groups (n=10) with 0.3-mm (group 1), 0.5-mm (group 2), and 0.7-mm (group 3) core thicknesses. The copings were placed on the dies and randomly coded. The vertical gap was measured at 10 points on the margin under a scanning electron microscope (SEM). After porcelain sintering, the crowns were placed again on the dies, and the vertical gap was measured again at the same points. Data were analyzed using analysis of variance (ANOVA) and paired t-test.

Results: There was a significant difference among the three groups in marginal gap ($P<0.05$). The comparison of marginal gaps before and after porcelain sintering showed no significant changes with 0.3-mm and 0.5-mm thicknesses ($P>0.05$) but the difference was statistically significant with 0.7-mm core thickness ($P<0.05$).

Conclusion: It may be concluded that by increasing the zirconia core thickness, the marginal gap of all-ceramic crowns decreases. Regarding 0.3-mm and 0.5-mm core thicknesses, porcelain sintering had no effect on marginal gap but regarding 0.7-mm core thickness, marginal gap increased after sintering.

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Introduction:

Marginal adaptation of full-coverage restorations is an important factor affecting their long-term success.[1,2] The material and the thickness of the core affect the marginal adaptation of restorations.[1,3] It has been shown that 73.9% of zirconia fixed partial dentures exhibit problems in terms of marginal fit.[4] A poor marginal adaptation can increase microbial plaque accumulation and can lead to changes in the subgingival microbial flora. [5,6] It can also cause gingival inflammation and discoloration of gingival margins.[7-10] In more severe cases, increased pocket depth and loss of attached gingiva may occur.[11-14] The development of tooth decay and periodontal disease in such cases may even result in treatment failure and subsequent tooth loss.[6,7] By an increase in marginal gap, the luting cement is further exposed to the oral environment. Considering the solubility of most dental cements in the saliva, this can result in treatment failure. Moreover, poor adaptation of all-ceramic crowns compromises the fracture strength of these restorations.[15,16]

On the other hand, all-ceramic restorations are among the most esthetic restorations currently available in the market due to their excellent translucency.[17] High-strength ceramics such as zirconium oxide (ZrO2), fabricated by the computer aided design/computer aided manufacturing (CAD/CAM) system, are particularly high demand due to their high flexural strength and fracture toughness. (18) However, studies on the marginal adaptation of partially sintered ZrO2 ceramics are limited.[18]

Studies comparing the effects of the material and the thickness of the core and porcelain sintering on marginal adaptation have yielded controversial results. Some studies have reported that porcelain sintering has no significant effect on the marginal adaptation of all-ceramic restorations. [19,20] In contrast, other studies have reported some degrees of marginal misfit after sintering of all-ceramic restorations compared to the baseline values measured before the sintering. [21,22]

Considering the gap of information on this topic and the present controversies, the current study aimed to assess the effect of porcelain sintering and the thickness of zirconia core on the marginal adaptation of all-ceramic restorations.

Materials and Methods:

In this in-vitro experimental study, a standard brass die, measuring 7 mm in length and 5 mm in diameter, was used. Using a milling machine, the brass die was prepared with a classic chamfer design with the depth of 0.8 mm. [23] The axial walls had a 10-degree taper towards the occlusal surface. (24) The incisal edge was also beveled to provide a smooth and uniform path of insertion for the copings. The sample size was calculated to be 30 (10 specimens for each core thickness) according to a previous study. [24]

Copings were fabricated using a CAD/CAM system (inLab MC XL, Dentsply Sirona, Beinsheim, Germany). The metal die was scanned by inEos scanner (Dentsply Sirona, Beinsheim, Germany), and three-dimensional (3D) images were obtained. The images were reconstructed and processed using inLab MC XL.[25] The specimens were divided into three groups of 10 samples with 0.3-mm, 0.5-mm, and 0.7-mm core thicknesses. The thickness of the die spacer was considered to be 35 µm. The pre-sintered zirconia blocks were milled in MC XL milling machine. After the completion of milling, the accuracy of the thicknesses was checked and then the zirconia coloring liquid was used to code different thicknesses (A3 shade for 0.7-mm thickness, A2 shade for 0.5-mm thickness, and A1 shade for 0.3-mm thickness). The copings were then sintered in Sintramat furnace (Ivoclar Vivadent, Schaan, Liechtenstein, Germany) for 8 hours at 1500°C to 1600°C. Before sintering, crowns were placed on the dies using a clamp (Figure 1)

Figure 1. Coping placed on the standard die

Result:

Kolmogorov-Smirnov test showed normal distribution of the data in the three groups (P=0.25). Levene's test confirmed the equality of variances (P=0.25). Repeated measures ANOVA showed a significant difference in changes between the groups (P=0.043). Thus, one-way ANOVA was used to compare the marginal gap among the three core thicknesses, which revealed a significant difference in marginal gap among the three core thicknesses (P<0.0001). Tukey's HSD test revealed significant differences between the three groups (P<0.001). The highest mean marginal gap was noted with 0.3-mm core thickness, and the lowest mean marginal gap was noted with 0.7-mm core thickness. By an increase in core thickness, the marginal gap significantly decreased (P<0.05). Tables 1 and 2 show the mean marginal gap in the three groups before and after sintering.One-way ANOVA was used to compare the marginal gap among the three thicknesses after sintering, which revealed a significant difference (P=0.0001).

The highest mean marginal gap was noted with 0.3-mm core thickness, and the lowest mean value was noted with 0.7-mm core thickness. Thus, by an increase in core thickness, the marginal gap significantly decreased. The marginal gap did not show a significant difference before and after sintering in 0.3-mm thickness of zirconia core (P=0.79). The correlation between the amount of marginal gap and porcelain sintering was not significant (P=0.20).

The marginal gap did not change significantly before and after sintering in 0.5-mm thickness of zirconia core (P=0.84). The correlation between the amount of marginal gap and porcelain sintering was not significant (P=0.83).

There was a significant difference in marginal gap before and after sintering in 0.7-mm thickness of zirconia core (P=0.02). The correlation between the amount of marginal gap and porcelain sintering was not significant (P=0.83).

Table 1. Marginal gap (µm) before porcelain sintering (n=10)

Core thickness \ Marginal gap	Mean	SD	Minimum	Maximum	95% CI Lower bound	95% CI Upper bound	P-value
0.3 mm	89.21	28.90	57.5	139.7	68.52	109.89	0.0001
0.5 mm	79.55	39.32	79.55	39.32	51.41	107.68	
0.7 mm	8.40	3.10	8.40	3.10	6.17	10.62	

Table 2. Marginal gap (µm) after porcelain sintering (n=10)

Core thickness \ Marginal gap	Mean	SD	Minimum	Maximum	95% CI Lower bound	95% CI Upper bound	P-value
0.3 mm	93.30	26.92	49	140	74.03	112.56	0.0001
0.5 mm	82.5	22.4	58	139	66.43	98.56	
0.7 mm	13.4	4.5	6	21	9.96	16.92	

SD=Standard Deviation, CI=Confidence Interval

Discussion

A successful restoration in the oral cavity must have optimal mechanical, biological, and esthetic properties.[27,28] Porcelain-fused-to-metal (PFM) restorations have been the restorations of choice for many years. However, they have dubious biological and esthetic characteristics. The use of all-ceramic restorations has significantly increased due to major improvements in their technique of production and materials.[29] Marginal adaptation is important for the success of fixed restorations.[27,28] A poor adaptation may result in the development of caries, gingival inflammation, and bone loss, compromising tooth vitality; this is more significant in all-ceramic restorations. [30-32]

The current study assessed the effect of porcelain sintering and zirconia core thickness on the marginal adaptation of all-ceramic restorations. The results showed that the marginal gap was clinically acceptable (less than 120 µm) in the three groups.[33] Thus, all three zirconia core thicknesses can be successfully used in the clinic. The mean marginal gap with 0.7-mm thickness of zirconia core was 8.40 µm before and 13.40 µm after sintering; these values were significantly lower than the values related to 0.5-mm and 0.3-mm core thicknesses before and after sintering. Thus, 0.7-mm thickness of zirconia core provides better marginal adaptation. Therefore, it is logical to expect that caries recurrence would have a lower frequency in use of 0.7-mm thickness of zirconia core compared to other thicknesses.

Jalalian et al compared the marginal gap of all ceramic crowns using 0.3-mm, 0.5-mm, and 0.7-mm core thicknesses.[34] Similar to our study, 0.7-mm core thickness exhibited the least marginal gap in comparison with other thicknesses. [34]

The marginal gap levels obtained in our study are comparable to those reported by Bindl and Mormann.[2] They compared the marginal gap and internal adaptation of CAD/CAM all-ceramic crowns. They used tools similar to those implemented in our study (CAD/CAM and SEM) and showed that the internal marginal adaptation of CAD/CAM crowns was less than that of In-Ceram. [2] Vigolo and Fonzi evaluated the effect of porcelain sintering cycles on the marginal gap in Procera, Lava (CAD/CAM), and Everest systems and reported no significant difference in marginal misfit before and after porcelain sintering,[19] which was in agreement with our findings regarding 0.3-mm and 0.5-mm core thicknesses.

Pak et al compared the marginal gap of all-ceramic crowns fabricated using Digident and Lava systems before and after sintering and showed significant differences in the marginal gap of each group before and after sintering but Lava and Digident systems were not significantly different in this respect.[22]

The main cause of marginal misfit is porcelain shrinkage during sintering. Due to the density and high strength of zirconia copings, the sintering cycle has an insignificant effect on their marginal adaptation. However, adequate information on the mechanism of the effect of the sintering cycle on marginal adaptation is not available,[21] and further studies are required in this respect.

To assess the accuracy of restorations, measurements should be made in the horizontal and vertical planes. In the current study, only the vertical marginal gap was evaluated, which can be considered as a limitation. Similar studies are required to measure marginal gap in both horizontal and vertical planes. Also, we did not simulate the mechanical loads applied to the restorations in the oral cavity, which is another limitation. Moreover, our study had an in-vitro design. Thus, the generalization of the results to the oral environment should be done with caution.

An adequate sample size and use of SEM, which is a well-accepted tool for assessment of marginal adaptation in vitro, [2] were among the strengths of our study. Clinical trials are required to confirm our results.

Conclusion

Within the limitations of this in-vitro study, it may be concluded that by an increase in zirconia core thickness, the marginal gap of all-ceramic restorations also decreases. In use of 0.3-mm and 0.5-mm thicknesses of zirconia core, porcelain sintering has no significant effect on the marginal gap. However, sintering increases the marginal gap of 0.7-mm-thick zirconia cores.

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