Original Article

In Vitro Effect of Porcelain Firing Cycle and Different Thicknesses of IPS E.max CAD Core on Marginal Accuracy of All-Ceramic Restorations

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Abstract
Objectives: Marginal adaptation is important for long-term success of full-coverage restorations. The aim of this study was to determine the effect of porcelain firing cycle and different thicknesses of IPS e.max core on marginal accuracy of all-ceramic restorations.
Materials and Methods: A standard stainless steel die with 0.8 mm classic chamfer finish line and 10° taper was used in this in vitro study. An impression was taken from the stainless steel die to fabricate 20 epoxy resin dies, which were then scanned and IPS e.max CAD cores were fabricated using computer-aided design/computer-aided manufacturing (CAD/CAM) technique in two groups of 10 with 0.7 mm (group A) and 0.4mm (group B) core thickness. Copings were then placed on their respective dies and randomly numbered. The amount of marginal gap was measured in 10 points under a stereomicroscope (×90 magnification) before and after porcelain veneering.
Results: The mean gap in 0.7mm and 0.4mm core thicknesses was 15.62±2.55µm and 19.68±3.09µm before porcelain firing and 32.01±3.19µm and 35.24±3.8µm after porcelain firing. The difference in marginal gap between the two thicknesses was significant before porcelain firing but not significant after veneering. Significant differences were also found in the marginal gap before and after porcelain veneering in each group.
Conclusion: The porcelain firing cycle increases marginal gap in IPS e.max CAD restorations; 0.3 mm decrease in core thickness slightly increased marginal discrepancy, however it was not significant.

Key words: Dental Porcelain; IPS e.max CAD LT; Ceramics; Computer-Aided Design
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INTRODUCTION

The restoration margin is susceptible to failure biologically and mechanically regardless of the type of restoration [1]. A well-adapted and finished margin will decrease bacterial plaque accumulation [2-4] and subsequent development of recurrent caries and endodontic [5,6] and periodontal diseases [2].

All ceramic restorations are highly demanded by patients because they are esthetically pleasant and their use eliminates the need for subgingival placement of restoration margins for esthetic purposes [7]. Moreover, these restorations provide precision of fit, which is important for long-term success. However, distortion of all-ceramic restorations may occur during the manufacturing process, causing marginal discrepancy [8]. Misfit of the restoration exposes the luting cement to the oral environment [9]. Since most dental cements are soluble, bacterial plaque can easily accumulate in this area and result in development of gingival inflammation, caries and pulpal lesions. In addition, marginal misfit can cause stress concentration and decrease the strength of the restoration leading to its eventual fracture [8,10].

Factors influencing the marginal fit include finish line configuration, cement space, taper of preparation, manufacturing technique, cementation, porcelain veneering and firing cycles [11]. McLean and von Fraunhofer proposed that a restoration would be successful if marginal gaps and cement thicknesses of < 120µm could be achieved [12].

Advances in dental ceramic materials and processing techniques increased the strength and improved the marginal fit of ceramic restorations. Among them, CAD /CAM and milling technology have greatly facilitated the fabrication of high-quality dental ceramics [13]. In the CAD/CAM technique, a core is veneered by a layer of ceramic. Thermal ceramic–ceramic incompatibility introduces residual stresses; thus, multiple firing of ceramics may influence the coefficient of thermal expansion and affect the compatibility of ceramic materials [14]. Several studies have indicated that marginal adaptation of metal ceramic restorations is influenced by the firing cycles of porcelain. Balkaya et al. [15] investigated the influence of firing cycles on the marginal distortion of ceramic crowns. They reported that high temperatures during the porcelain firing cycle led to marginal discrepancy. Patteno et al. [16] evaluated the marginal fit of three different metal-ceramic systems and showed that marginal gaps were affected by the application of ceramic and by the alloy used for the substructure. Att et al. [17] measured the marginal adaptation of three different zirconium dioxide three-unit fixed partial dentures. They found that the marginal accuracy of zirconia fixed partial dentures was influenced by the manufacturing technique.

In contrast, other studies concluded that the impact of porcelain veneering on marginal fit was not significant.

Bhowmik and Parkhedkar [18] studied the effect of firing cycles on marginal fit of glass-infiltrated alumina copings fabricated using two different techn-iques and demonstrated statistically insignifi-cant change in marginal gap following the application of the veneering porcelain. Vigolo and Fonzi [19] evaluated the fit of zirconium-oxide-based ceramic four-unit fixed partial dentures fabricated with three different CAD/CAM systems before and after porcelain firing cycles and after glazing cycles.

They observed that the porcelain firing cycles and the glazing cycles did not affect the marginal fit of zirconium-oxide-based ceramic CAD/CAM systems.

Sulaiman et al. [20] compared marginal fit of three all-ceramic crown systems (In-Ceram, Procera, and IPS Empress) and found no significant differences among the three stages of crown fabrication namely the core fabrication, porcelain veneering and glazing.

The fit of all ceramic crowns is a concern for clinicians despite the manufacturer's claim of their superior fit. Hence, this study aimed to evaluate the effect of porcelain firing cycle and different thicknesses of IPS e.max CAD core on marginal accuracy of all ceramic restorations.

MATERIALS AND METHODS

A stainless steel die (Fig. 1) was fabricated to simulate a premolar based on its average dimensions according to Ash and Nelson [21] with 7 mm length and 5 mm diameter. The die had a flat-end conical shape, 0.8 mm classic chamfer finish line all around and 10° taper as recommended by the manufacturers and previous studies [11,22,23]. For the fabrication of conventional copings, the metal die was duplicated with silicone impression material (Speedex; Coltene Whaledent AG, Altstätten, Switzerland).

Fig. 1. Stainless steel die

Fig. 2. IPS e.max coping on the respective die

Epoxy resin (Die Epoxy, American Dental Supply Inc., Allentown, PA, USA) was poured into the impression to create a pattern, which was used to fabricate copings. The thickness of copings was measured by a digital caliper (Iwanson decimal caliper 2550-2; ASA Dental, Bozzano, Italy). A die was scanned with a CAD scanner (Sirona Dental GmbH, Wals, Austria). The data were subsequently transferred to the CAM system to design 20 copings (10 copings per group). The coping margin thickness of 0.4 mm for group A and 0.7 mm for group B on a 35-micron die spacer were modeled by a single technician.

The presintered blank IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein) was then milled to fabricate the ceramic coping (Fig. 2). Finally, the copings were sintered in a furnace (Ivoclar Vivadent, Schaan, Liechtenstein) for seven minutes at 820-850°C. To confirm the reproducibility of placing and removing the copings from the metal dies, orientation grooves were created on the die and the coping. Measurements of the marginal gap were made in the vertical planes as the maximum distance between the finished surface of the underlying prepared tooth and cervical margin of crown using a stereomicroscope (SZ-12, Olympus, Tokyo, Japan) at ×90 magnification and a camera (DP 72, Olympus, Tokyo, Japan) with a computer software (professional analysis) to measure the marginal gap on the magnified images at 10 sites (Fig. 3).

In order to verify the effect of porcelain veneering on the marginal adaptation, the measurements were made in two different phases of crown fabrication process: The first measurement was made after sintering of the coping and the second measurement was made after the veneering process (feldspathic porcelain was applied to the substructure using the silicone key). The first measurement in each group was considered as the baseline and the alterations in the marginal fit of copings after the firing cycles were evaluated. The analysis of the data was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). The independent sample t-test was used to find significant differences between the two different thicknesses of copings and paired t-test was used to evaluate marginal discrepancies after the firing cycle.

RESULTS

This study was performed on 20 samples in two groups with thicknesses of 0.7 mm in group A and 0.4 mm in group B, before and after porcelain firing cycle. The gap in each sample was measured in 10 points. Two variables including the mean gap of 10 points in each sample and the maximum amount of gap in all samples were analyzed. The mean marginal gap measured after core fabrication and firing of the veneering porcelain was 15.62±2.55µm and 32.01±3.2µm, respectively in group A and 19.68±3.09µm and 35.24±3.88 µm, respectively in group B.

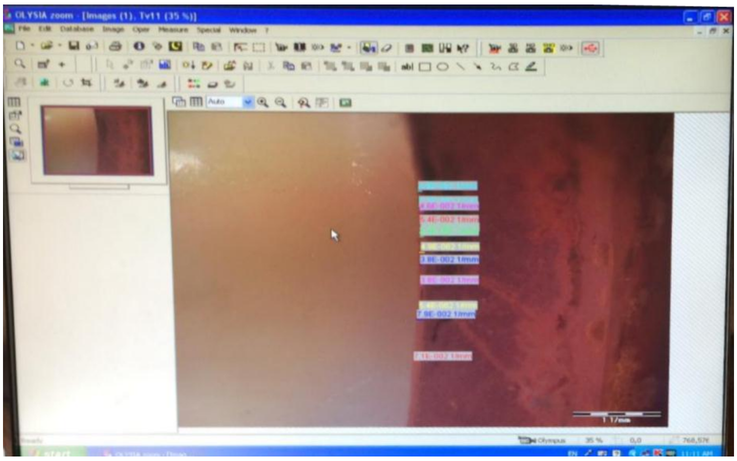

Fig. 3. Professional analysis software

A significant difference was found between the two groups in terms of marginal gap (P<0.005). Significant increase in gap was observed after the veneering stage in both groups (P<0.001). The results are shown in Fig. 4.

DISCUSSION

This study evaluated the effect of porcelain firing cycles and different thicknesses of IPS e.max CAD core on marginal accuracy of all ceramic restorations.

The results showed that changes in core thickness from 0.4 mm to 0.7 mm slightly decreased marginal discrepancy, however it was not significant. Also the veneering procedure significantly decreased marginal adaptation of the crowns (P<0.001).

In the current study, a stainless steel die was used as an abutment similar to other studies [15] because metal dies enable achieving a standard preparation for all crowns and also resist wear during the manufacturing process. The marginal design of the metal die was a classic chamfer, which is recommended by several researchers as reported in a systematic review [11]. Acceptable taper ranged from 6° to 15° in previous studies [22,23]. In the current study, 10° taper was applied. In some studies, sample size ranged from five to 10 samples in each test group [15,24]. Ten samples were selected for each test group in our study to compensate for minor variations during the fabrication process.

The methods for measurement of marginal fit include cross-sectional view, direct view of the crown on a die, impression replica technique and clinical examination [11].

The direct view is a nondestructive technique and is often used to measure the distortion during the manufacturing process of restorations [15]. In the current study, non-cemented, non-sectioned samples were examined via direct visualization under a stereomicroscope. Disadvantage of an optical microscope is the limited depth of view field. It is not possible to focus on two points on the same plane [25].

In the current study, an image analyzing software was used to overcome this problem, which allows superimposition of pictures of the same zone.

To confirm the reproducibility of placing and removing the copings from the metal die, orientation grooves were made on the die and the coping and the measurements were made at 10 points. In the current study, the initial measurement in each group served as the control, and the changes in the marginal fit of copings or milled crowns after the firing cycles were evaluated.

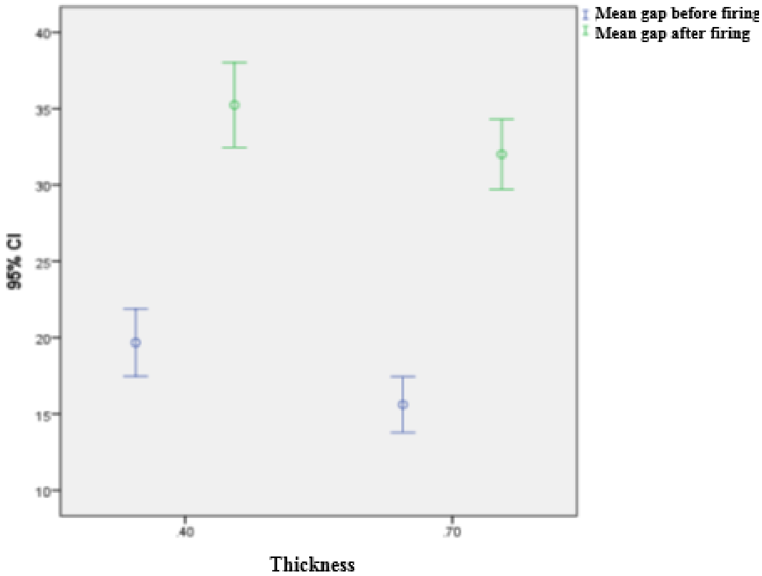

Fig. 4. Comparison of marginal gap between the two groups according to the fabrication stage

In the present study, the marginal gap of samples in group A with a thickness of 0.7 mm was 15.62µ after core fabrication and 32.01µ after porcelain firing; in group B with a thickness of 0.4 mm, these values were 19.68µ and 35.24µ, respectively. Therefore, in comparison with previous studies, the marginal discrepancy of IPS e.max crowns was in the clinically acceptable range and the results of the current study are in agreement with the values reported in previous studies.

Christensen [26] indicated that the clinically acceptable marginal gap ranged from 34 to 119µ for subgingival and 2 to 51µ for supragingival margins. However, McLean and von Fraunhofer [12] reported 120µ to be the maximum acceptable value. In an in-vivo study, Lofstrom and Barakat [27] measured the supragingival margins of clinically well-fitting crowns using a scanning electron microscope and reported marginal discrepancy values in a range of 7 to 65µ.

In the current study, the marginal gap increased in each stage of fabrication. Significant increase ($P<0.001$) was found after firing cycle. This result agrees with several studies.

Balkaya et al. [15] reported that the firing cycles influenced the marginal integrities of copy-milled ceramic crowns in the vertical plane at the labial and palatal surfaces that could result in occlusal displacement of the crown. Also, Cho et al. [28] showed that the marginal gap increased in pressed ceramic single crowns during the application of the veneering porcelain. Bajaj [29] stated that all-ceramic system showed continued marginal discrepancy through all firing cycles; however all-ceramic system showed less distortion compared to metal ceramic systems. Aboushelib et al. [30] studied the internal adaptation and marginal accuracy of ceramic laminate veneers and demonstrated that the manufacturing process influenced the internal and marginal fit of ceramic veneers. In contrast, some studies demonstrated no significant difference in this respect in the firing cycles. Sulaiman et al. [20] found no significant changes during crown fabrication stages. Bhowmik and Parkhedkar [18] demonstrated statistically insignificant change in marginal gap following the application of the veneering porcelain. Vigolo and Fonzi [19] observed that the porcelain firing cycles and the glazing cycles did not affect the marginal fit of zirconium-oxide-based ceramic CAD/CAM systems. Beschnidt and Strub [31] discussed the factors influencing the measurement of marginal gap such as cementation, aging process after cementation, type of microscope and location and number of measured sites. Creating a space between the die and the prosthesis for the cement layer is known to significantly improve adaptation [11,32]. In our study, measurements were made before cementation. Measurements made solely after cementation do not allow for the determination of the relative impact of cementation on marginal fit [33]. Jorgensen and Petersen [34] found that cementation significantly compromised marginal fit. Besides, it is more convenient to perform measurements prior to cementing the crown and this is what Jorgensen and Petersen did [34].

Additionally, the results showed that 0.3 mm increase in core thickness had no effect on the marginal accuracy of crowns. Farid et al. [35] evaluated the influence of core thickness and fabrication stages on the marginal accuracy of IPS e.max Press crowns. They concluded that 0.2 mm increase in core thickness had no effect on the marginal fit of crowns and demonstrated that the critical factor in marginal accuracy was the variations in thickness of the veneering porcelain in one crown rather than uniform change in thickness of the veneering porcelain or the core.

CONCLUSION

This study evaluated the marginal adaptation of IPS e.max CAD crowns in two thicknesses of 0.7 mm and 0.4 mm and revealed that:

1. Changes in core thickness from 0.4 mm to 0.7 mm slightly decreased marginal discrepancy, however it was not significant. Thus, it is recommended to use minimum thickness in order to be conservative and obtain improved esthetics.
2. Porcelain firing cycle and veneering procedure increased marginal gap.
3. Based on our findings, the marginal gap of IPS e.max CAD in both thicknesses of core and after firing was in the clinically acceptable range.

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