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Comparative evaluation of the fit of ceramic inlay restorations fabricated with heat-press technique and CAD/CAM systems: A preliminary study

Merve Benli

From, Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Istanbul University, Istanbul, Turkey.

Correspondence to: Dr.Merve Benli, Assistant Professor, Istanbul University, Dis Hekimligi Fakultesi Topkapi Mahallesi, Turgut Ozal Millet Cd, 34093 Fatih/Istanbul, Turkey, E Mail: benlimerve@hotmail.com

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ABSTRACT

Objective: The objective of this in-vitro study was to evaluate the marginal and internal fit of a lithium disilicate inlays fabricated by two CAD/CAM systems (extra-oral and intra-oral scanning), and conventional heat-press technique. **Materials and methods**: Mandibular first molars were used for inlay restorations in a typodont model. Three groups (n=12 each) of inlays were fabricated by Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) technology using intraoral and extraoral scanning devices, and conventional heat-press method. Replica technique was used to assess the discrepancies. Internal and marginal gaps were measured at 4 points on each side with stereomicroscope at 200x magnification. One-way variance analysis test (ANOVA) and paired-samples t-test were used for analyzing the results. **Results**: The fit values were statistically significantly influenced by the production method in total discrepancy comparisons (p= .000). Intraoral scanner group demonstrated the lowest marginal and internal gap values whereas conventional heat-press group showed the highest results. Statistically significant differences were found for fit values with respect to the groups (p<.001). **Conclusion**: Within the limitations of the study, restorations fabricated via complete digital workflow demonstrated better marginal and internal accuracy than silicone impressions with conventional heat-press technique.

Key words: *CAD/CAM, inlay, marginal fit, internal fit.*

Increasing demand for esthetic posterior restorations has played a role in the growth of new materials and manufacturing techniques nowadays [1]. Composites and ceramics are the most preferred materials by the clinicians in the fabrication of posterior indirect restorations. When these two are evaluated in themselves, it is seen that the ceramic is the preferred material because of biocompatibility, superior esthetics, and masticatory force resistance [2]. All-ceramic inlays are mainly fabricated from feldspathic or lithium disilicate–based materials and demonstrate higher wear and compressive resistance than composite ones [3]. Adhesively cemented partial or full coverage all ceramic restorations are admitted as a good alternative to conventional full crowns, because of having more conservative technique in restoring the loss of tooth structure [4].

Marginal and internal fits are vital parameters for restorations, particularly for ceramic inlays, to reduce the risk of marginal ditching or deterioration of the luting agent [5]. The existence of marginal gaps concludes in dissolution of the luting cement by exposing it to oral cavity, substantial wear with physical fatigue, increased microleakage, and loss of bonding [6-10]. Moreover, poor adaptation to the tooth surface can affect the longevity of the restorations negatively [11]. In the literature, an in-vitro study found mean marginal gap values of 150 to 168 µm for mesio-occluso-distal (MOD) ceramic inlay restorations produced with computer aided design/computer aided manufacturing (CAD/ CAM) systems [12]. Industrially pre-fabricated machinable ceramic materials for CAD/CAM techniques have been suggested as an option for conventional method [13]. Lithium disilicate ceramic material, which is mostly preferred in CAD/CAM systems, was used in this study due to improved strength and other physical properties. CAD/CAM system which is named AC Omnicam used in the fabrication of the inlay restorations is the latest version of the Cerec system. This system is one of the most up-to-date digital systems presented to the dental market and there is not enough study about its fabrication characteristics in the literature. Furthermore, insufficient data are present regarding marginal adaptation of ceramic inlays manufactured with new CAD/CAM devices.

Internal adaptation is also a crucial step for the durability of full ceramic restorations [14]. The thickness of the luting agent, affected from internal adaptation, is one of the significant factors influencing the failure mode of monolithic restorations. According to the theory of ceramic failure, it has been reported that the cement interface layer of the restoration plays a role in crack initiation. Radial flexural cracks initiating from the internal surface of the cement can reach to the margin area or occlusal surface, and finally cause bulk fracture failure of the restoration [15]. Consequently, the thick layer of the cement agent, which is the result of poor internal adaptation, is an undesirable condition as it significantly reduces durability of ceramic materials [16]. Besides, another factor that increases the importance of the marginal and internal fit is the high configuration factor of the inlay restorations which exposes the restoration to polymerization shrinkage [17]. Indirect restorations are at the forefront to eliminate polymerization shrinkage as possible [18]. When the forces which consisted from the polymerization shrinkage overextend the efficacy of adhesion and the system's elastic or plastic deformation, cohesive or adhesive fracture failures may take place. Hence, adequate restorative adaptation is an essential factor to obtain maximum physical reinforcement of ceramic from the underlying tooth structure and cement agent [19]. Nevertheless, there is scarce amount of data about the internal fit of ceramic inlay restorations.

The aim of this in-vitro study was to assess the internal and marginal fit of inlays produced by conventional heat-press method and CAD/CAM technology with the aid of different digital techniques, and their related workflow. The null hypothesis was that there was no difference existing in internal and marginal fit of inlay restorations with different fabrication techniques.

MATERIALS & METHODS

Three groups (n=12 each) of inlays were fabricated by CAD/CAM technology using intraoral and extraoral scanning devices, and conventional heat-press method. A mandibular left first molar on a typodont model (Frasaco ANA-VCER; Frasaco GmbH, Seefeld, Germany) was prepared to obtain inlay restorations. Uniformed MOD inlay cavities with rounded angles and flat pulpal floors were prepared with diamond rotary instruments (#271252, Eco, Germany) on a high-speed handpiece under a dental surgical microscope (Extaro 300, Zeiss GmbH, Oberkochen, Germany). Burs were changed in every six preparations and all the preparations were performed by one experienced clinician. Occlusal cavity width was adjusted to 2 mm, and the depth was set to 2 mm according to the occlusal margin. Cervical margins of the proximal boxes were prepared to be 1 mm over the cementoenamel junction. The depth and the width of the proximal boxes were 4 mm with 900 cavosurface margins. Occlusal taper of lingual and buccal walls of the proximal boxes was about 120, adjusted by using a surveyor.

In the group H, as control (conventional heat-press group), impressions were made with polyvinyl siloxane material (light and heavy body; Imprint 3;3 M ESPE, Seefeld, Germany). Impressions were poured with type IV gypsum to obtain models (Elite Rock stone, thixotropic, Lot 8641, Zhermack SPA, Rovigo, Italy). Die spacer (Euro Quick Set 10 µm; Kerr Dental Laboratory Products, Orange, CA) was applied as two uniform layers to the coronal part of the dies, locating 0.5 mm above of the margins. Restorations were produced from lithium disilicate glass-ceramic material with conventional heat-press method according to reference study [12].

In the group I, an intraoral digital scanner, CEREC AC Omnicam (Sirona Dental Systems, NY, USA), was used for the impressions according to the manufacturer's recommendations. In the group E, an extraoral scanner, InEosX5 (Sirona Dental Systems, NY, USA), was used for data obtaining. Titanium dioxide powder (ESPE Lava scan powder; 3M ESPE) was used to arrange the master model before scanning. The cement space in the software of the CAD/CAM system was programmed at 40 µm for two digital impression groups, according to the CEREC manufacturer. The obtained data for both groups were evaluated and checked on the system and the required regions were renewed. After revising the obtained data for precision, files were sent to the confirmed laboratory and centers, for processing of the digital impressions. Restorations from groups I and E were designed and fabricated with the system (CerecinLab, 3D Software V3.01, Sirona, Bensheim, Germany) from lithium disilicate glass-ceramic blocks (IPS e.max CAD, IvoclarVivadent, Schaan, Liechtenstein). After the milling procedure, final sintering and glazing procedures of inlays were completed.

To evaluate the fit of inlays, replica technique was preferred [20]. Silicone replicas were obtained from two light-body addition silicones (Express 2 Ultra-Light Body Quick, 3M ESPE, USA; Bonasil A+ Light HTS Bonasil A, DMP, Florida, USA). Marginal fit was measured at four locations of the occlusal area and at four sites on the pulpal, buccal, and lingual walls in proximal margins. For internal fit, replicas were cut mesio-distally, and one half-portion was utilized to measure wall thickness. For the evaluation of the internal and marginal accuracy of the inlays, a stereomicroscope (M-80, Leica, Wetzlar, Germany) with a digital camera (Hitachi CCTV HV-720E, Hitachi, Tokyo, Japan) was utilized to transfer all the captured images. Furthermore, a suitable personal computer for the Microsoft NT 4.0 operating system, and an image-analysis program (Leica Application Suite, Leica, Wetzlar, Germany) were used to evaluate the measurements. Internal and marginal fit measurement procedure was performed on the computer screen under magnification factor of 200x.

Statistical analysis was performed using the Number Cruncher Statistical System program (NCSS). Shapiro Wilk test was utilized to control the normality distribution. As the data agreed with normal distribution, the one-way analysis of variance (ANOVA) and paired-samples t-test were used in the comparison. Analysis results were presented as mean ± standard deviation (SD). The results were assessed at $p<0.05$ significance level.

RESULTS

Marginal and internal discrepancies were displayed for each test group in Table 1 and Table 2. The fit values were statistically significantly influenced by the production method in total discrepancy comparisons ($p= 0.000$). Group I, in which intraoral scanner was used, demonstrated the lowest marginal and internal gap values whereas group H, conventional heat-press group, showed the highest results. Statistically significant differences were found for fit values with respect to the groups ($p<0.001$).

Table-1: Comparison of marginal gap values between groups.

GROUP	Occlusal	Proximal
H	115.4 ± 7.4a	123.6 ± 6.1a
E	97.2 ± 2.7b	99 ± 2.8b
I	75.9 ± 3.5c	69.1 ± 3.3c
Test statistic	412.2	943.9
p	<0.001	<0.001

a-c: There is no difference between groups with same letter for each surface. F: One-way variance analysis test statistic.

Table-2: Comparison of internal gap values between groups.

GROUP	Pulp	Axial
H	203.5 ± 13.1a	233.9 ± 12.6a
E	170.6 ± 6b	166.6 ± 5.9b
I	110.5 ± 7.4c	84.9 ± 5.8c
Test statistic	F:669.5	F:1949.4
p	<0.001	<0.001

a-c: There is no difference between groups with same letter for each surface. F: One-way variance analysis test statistic.

Accuracy comparisons within groups were demonstrated in table 3 and table 4. The highest marginal gap value was seen in proximal view of the group H (123.6±6.1 µm), and the highest internal gap value was detected in axial view of the same group (233.9±12.6 µm) ($p<0.001$).

Table-3: Comparison of marginal gap values within groups.

GROUP	Occlusal	Proximal	Test statistic	p
H	115.4 ± 7.4	123.6 ± 6.1	t= -5.083	<0.001
E	97.2 ± 2.7	99 ± 2.8	t= -2.445	0.023
I	75.9 ± 3.5	69.1 ± 3.3	t= 6.278	<0.001

t: Paired samples t test

Table-4: Comparison of internal gap values within groups.

GROUP	Pulp	Axial	Test statistic	p
IN-1	203.5 ± 13.1	233.9 ± 12.6	t= -7.598	<0.001
IN-2	170.6 ± 6	166.6 ± 5.9	t=2.004	0.057
IN-3	110.5 ± 7.4	84.9 ± 5.8	t= 15.800	<0.001

t: Paired samples t test

DISCUSSION

The aim of this in-vitro study was to investigate the effect of different fabrication techniques (CAD-CAM vs. press) on the internal and marginal fit of all-ceramic inlay restorations. The null hypothesis described that there was no difference existing in internal and marginal fit of inlays with different fabrication techniques was rejected.

In this study, heat-press produced inlays had highest values for internal and marginal gaps while intraoral scanner group (group I) showed lowest mean values, which means best fit, for all results. It was seen from the study that groups showed better gap values than another current paper, which used the same methodology with this study, except from the values of axial walls in heat-press group [21]. This result may be due to the performance of the technician or not performing any adjustments to the restorations prior to the measurements. According to the analysis, it was seen that the type of fabrication method had an obvious effect on the study results.

When considering the scarce amount of study, as only limited number of researches on CAD/CAM produced partial coverage restorations exist for reference, gap values of the study groups were slightly higher than those studies for inlay restorations fabricated with lab-side and chair-side CAD/CAM systems, performed similar to our study [16,17]. Besides, extraoral scanner group (group E) values for marginal fit were lower than the study reported by Pelekanoset al. for the CerecinLab (187.64 ±82.49 μm) [22]. This may be resulted from the selected measuring techniques, measurement points, different restoration designs, spacer adjustments, and glaze procedure for restorations. Furthermore, the powder used to capture the image by the digital scanner for extraoral scanning may have an impact on the results.

The internal fit of ceramic inlays is expected to be uniform, as the ideal value for spacer thickness is controversial. This value should be enough to allow for providing a complete seating of the restoration but should not be too wide to prevent excessive thickness [23]. The mean internal fit of the group H was significantly lower than the CAD/CAM groups (Group E and I). These values were in accordance with the study reported by Addi et al. or the heat-press technique, while Keshvad et al. reported lower internal gap values for this technique [24,25]. These results may be derived from different measuring techniques and one cross-section results which may not indicate the whole internal fit. Internal fit values of CAD/CAM groups of this study were within the limits in the literature which were reported by previous studies [24,26].

The main variables which may influence the accuracy of the CEREC system are operator variables, like clinical skills and the level of specialty with the system's machine. The others are intrinsic restrictions of the devices such as the milling machine, the software program, hardware restrictions within scanning equipment, and the design algorithms employed to create proposed restoration [5]. Furthermore, inconsistent size of cutting equipment can contribute to fit changes and influence marginal properties of the CAD/CAM restorations. With the growing progress of the technology and design algorithms, the precision of the CAD/CAM systems has been developed widely [27]. Obtained values in the present study which support the knowledge of better internal and marginal fit of CAD/CAM produced restorations can be derived from these factors.

The limitations of the present study contained: (1) Typodont teeth, which vary in physical features from natural tooth, were utilized in the study; (2) the study design was in-vitro style, so the results may not express real clinical situation; (3) for fabrication of CAD/CAM restorations, standard software settings (marginal ramp and spacer) were selected; and (4) fit values were limited to the pre-determined measurement points with silicone replicas in two dimensions. Along with these limitations, further studies are recommended to evaluate the suitability of different data capture devices and digital systems.

Finally, results of this study are suitable for all-ceramic system and production methods with its determined preparation type. Non-retentive and simplified preparation types may show more favorable results and are the purpose of future research. To evaluate clinical outcomes of this topic, prospective long-term researches are recommended for all ceramic restorations.

CONCLUSION

Within the limitations of this in-vitro study, we reached the conclusion that the heat-press production method for all ceramic inlays displayed significantly higher internal and marginal gap values compared to the CAD/CAM groups. Study samples were within the clinically acceptable gap limits. Furthermore, within the CAD/CAM groups, the intra-oral scanning group had better marginal and internal fit values compared with the extra-oral scanning group.

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