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Marginal Adaptation of CAD-CAM Fabricated Ceramic Inlays: An in-Vitro Evaluation

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Abstract: ***Background**: Ceramic restorations can be fabricated by using traditional methods like heat-pressing as well as contemporary methods like Computer Aided Designing and Computer Aided Manufacturing (CAD-CAM). Existing evidence regarding the marginal adaptation of CAD-CAM fabricated ceramic inlays is contradictory. **Aim**: The main objective of the study is to determine the marginal gap widths of CAD-CAM fabricated lithium disilicate ceramic inlays in comparison with heat-pressed ceramic inlays using scanning electron microscopic examination. **Materials and methods**: Thirty-six intact, caries-free, maxillary first and second premolars were used in the study. Standardized class II disto-occlusal inlay cavities were prepared and were distributed into two groups of 18 specimens, each based on the method of fabrication. The two groups contained CAD-CAM (Group A), and heat-pressed ceramic inlays (Group B). In group A, the prepared inlay cavities were scanned with an intraoral scanner, designed, and milled from IPS e.max CAD blocks. In group B, the ceramic inlays were fabricated by manual impression making and lost wax technique using IPS e.max PRESS ingots and Programat EP 3010 furnace. The fabricated inlays were placed on the prepared cavities of the respective specimens. The scanning electron microscope was used to evaluate the marginal adaptation of specimens at 12 predetermined points for each specimen by a single examiner. The data were subjected to statistical analysis. **Results**: The mean marginal gap values for CAD-CAM group and heat-pressed were 83.27µm and 87.11µm, respectively. The CAD-CAM ceramic inlays exhibited better marginal adaptation than heat-pressed ceramic inlays with an insignificant difference between the two groups. **Conclusion**: CAD-CAM method of fabrication did not differ significantly from heat-press method when marginal adaptation property is considered. Moreover, all class II ceramic inlays exhibited minimal gap values. **Clinical relevance**: CAD-CAM fabricated ceramic inlays exhibited a comparable marginal adaptation with that of heat-pressed inlays. Thus, CAD-CAM fabrication is a better alternative to the conventional fabrication method, which can avoid multiple patient visits.*

Keywords: Marginal integrity; CAD/CAM; heat-pressed; class II inlays

1. Introduction

The definitive goal of restorative dentistry is to maintain the health and integrity of the stomatognathic system. There is an increase in demand for esthetic restorative materials nowadays. Composite resins, glass-ionomer cement, and compomers are the tooth-colored materials used for direct restorations. None of these materials are suitable for restoring areas of the tooth subjected to heavy occlusal stresses. In these areas, the use of ceramics is considered as the best option due to their superior esthetics, improved mechanical properties, and biocompatibility. Ceramic materials are available in a wide range and are fabricated by using different methods like sintering, casting, and heat pressing [1]. Tremendous advances in software technology revolutionized dentistry with improved precision and reduced fabrication time. Computer-aided designing and computer-aided manufacturing (CAD-CAM) software help in the processing of indirect restorations in one appointment [2], [3].

Marginal adaptation is vital for the longevity of restorations as it affects the clinical outcome. Marginal gaps and irregularities cause luting cement exposure, which may result in marginal leakage and dissolution of the luting cement. In such conditions, marginal gaps act as portals of entry for microorganisms and oral fluids that can lead to secondary caries, pulpal disease, and periodontal inflammation[4].

Several researchers [4]-[7] investigated the marginal integrity of CAD-CAM ceramic inlays and heat-pressed ceramic inlays, but the evidence was contradictory. Few studies [6] reported that heat pressed technique resulted in better marginal adaptation, whereas other studies [4], [7] reported better adaptation with CAD-CAM technique. Another study [5] reported an insignificant difference in the marginal integrity of CAD-CAM and heat-pressed technique. The available evidence is contradictory and inadequate as many studies compared different types of ceramics for different fabrication techniques rather than using the same type of ceramic with different fabrication techniques. Thus, the study aimed to determine the marginal adaptation of lithium disilicate ceramic inlays fabricated using CAD-CAM and heat-press techniques when assessed with a scanning electron microscope.

The null hypothesis tested was that there would be an insignificant difference in the marginal adaptation of CAD-CAM fabricated IPS e.max CAD ceramic inlays and heat pressed IPS e.max PRESS ceramic inlays.

2. Materials and Methods

The study protocol was approved by Institutional review board and Ethical Committee.

2.1 Screening and selection of specimens

The sample size estimation was done based on the marginal adaptation values of an earlier study[8]. Thirty-six extracted human maxillary premolars were selected for the study. Age and gender of the patient were not considered during the collection of specimens. The teeth were examined with magnifying loupes for fracture lines and minor defects. The inclusion criteria were fully formed intact maxillary premolars with crowns of 7±0.5mm width. Teeth with caries, fracture lines, cracks, noncarious defects, and restorations were excluded. Extracted teeth were handled as per Centre for Disease Control (CDC) and institutional guidelines.

2.2 Specimen preparation

All the samples were cleaned with an ultrasonic scaler to remove the surface deposits and polished with pumice to remove plaque and debris. Later they were immersed in a 0.1% thymol solution for disinfection and storage until the experimental period. The root portions of the teeth were wrapped in aluminum foil and mounted in acrylic resin. Standardized disto-occlusal cavities of 2mm buccolingual width and 2mm pulpal depth were prepared on occlusal surfaces of maxillary premolars. All these disto-occlusal cavities were prepared with intact mesial marginal ridges of 2mm thickness. Proximal box depth was 4mm occlusogingivally, and width was 4mm buccolingually. The gingival seat was placed 1mm cervical to the cement-enamel junction. A taper of 8 degrees per wall was maintained with a 90º cavosurface angle. Rounding of internal line angles was done to reduce stress concentration.

2.3 Grouping of specimens and restorative techniques

All the samples were allocated randomly into two groups (n=18) group A and group B. In group A (CAD-CAM group), the prepared inlay cavities were scanned with an intraoral scanner (3Shape TRIOS, Copenhagen, Denmark). Scanning was performed by positioning the scanner over the occlusal surface along a long axis such that all the cavosurface margins and the internal line angles were recorded completely. Later the proximal surfaces were scanned to get the final optical impressions. Subsequently, restorations were milled from IPS e.max CAD blocks using imes-icore milling machine. The restorations were glazed and crystallized using a ceramic furnace at 840°C. Surface contaminants were removed from the restoration using a brush and try in of restorations were done.

In group B (heat-pressed), the restorations were replicated using polyvinylsiloxane impression material, and dies were prepared using type IV gypsum. Wax patterns were fabricated and invested. Then they were placed in the preheated furnace, which was heated up to a temperature of 850ºC for 45 minutes. The assembled investment ring with IPS Alox Plunger was positioned centrally in the hot press furnace (Programat EP 3010) for heat pressing. The ring was left to cool to room temperature for 60 minutes, sectioned using a separating disk followed by microblasting and ultrasonic cleaning. The sprues were separated by using a fine diamond disk, and tints were added. After foundation firing for 20 minutes, ceramic inlays were then cleansed, seated on the master die, and the fit was verified.

2.4 Evaluation of marginal adaptation

The roots of the teeth specimens were sectioned horizontally 4mm apical to the CEJ. The specimens with restorations were gold sputtercoated (E1010 ion sputter) and evaluated using a scanning electron microscope at 10 kV and 800X magnification by a single examiner. The marginal adaptation was analyzed at 12 predetermined points, six points on the occlusal, and six points on proximal surfaces (Figure 1).

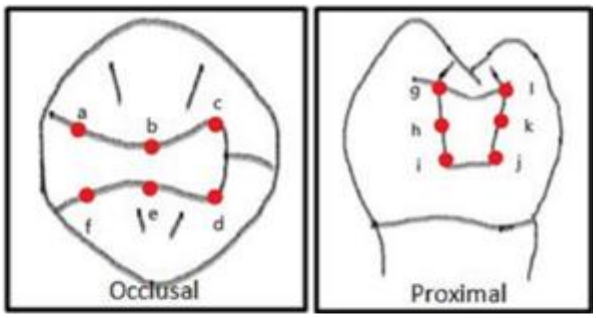

Figure 1: Predetermined points for marginal gap measurement

All the marginal gap values at 12 locations were recorded in micrometers (Figure 2 & 3) and averaged for every specimen.

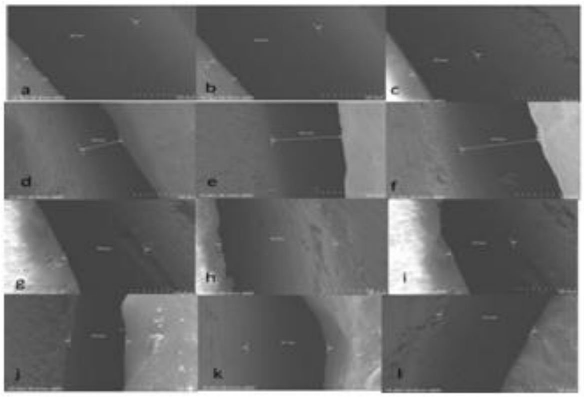

Figure 2: Scanning electron micrographs at a, b, c, d, e & f on occlusal surface and g, h, i, j, k & l on proximal surface of CAD-CAM ceramic inlays

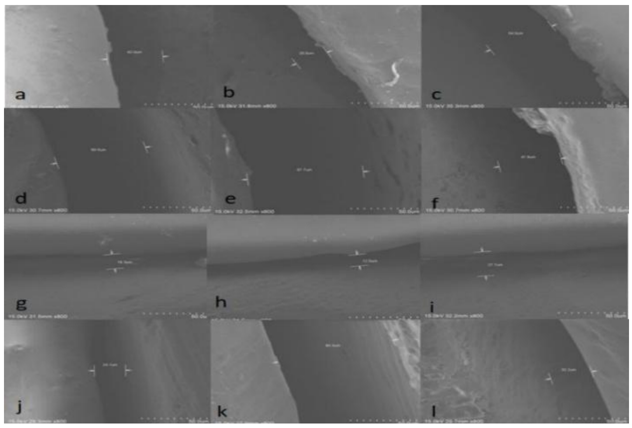

Figure 3: Scanning electron micrographs at a, b, c, d, e & f on occlusal surface and g, h, i, j, k & l on proximal surface of heat-pressed ceramic inlays

2.5 Statistical analysis

The data collected in the form of micrometers were entered in excel sheets and analyzed statistically employing SPSS software (Version 22.0, IBM, Armonk, NY). The Kolmogorov Smirnov test analyzed the normality of the marginal gap in the two groups. The marginal gap values between the two groups were compared using parametric independent t-test. The statistical analysis was performed at 95% confidence level, with the significance level established at p≤0.05.

3. Results

Marginal gaps, z value, and p-value of groups A and B are depicted in Table 1.

Table 1: Grouping and statistical analysis (Kolmogorov Smirnov test)

Group	Fabrication technique	Mean (µm)	Z-value	p-value
Group A - Lithium disilicate CAD-CAM (n=15) (IPS e.max CAD)	CAD-CAM technology using 3Shape intra oral scanner and imes-icore milling machine	83.27	0.6720	0.750
Group B - Lithium disilicate heat-pressed (n=15) (IPS e.max PRESS)	Heat-pressed technique using manual impression making and Programat EP 3010 furnace	87.11	0.4660	0.9820

For the statistical analysis, the Kolmogorov Smirnov test was used. The mean marginal gap in µm, standard deviation (SD), and standard error (SE) are depicted in Table 2 for two groups A and B.

Table 2: Intergroup comparison of marginal gaps (Independent t test)

Groups	Mean (µm)	SD	SE	t-value	p-value
Group A (CAD-CAM)	83.27	24.00	5.66	-0.4796	0.6346
Group B (Heat-pressed)	87.11	23.27	5.64		

Marginal gap values in two groups (A and B) follow a normal distribution. Hence, the parametric independent t-test was employed to analyze statistically (Table 2). The mean marginal gap in CAD-CAM group (83.27µm) is less than the mean marginal gap in the heat-pressed group (87.11µm), but the difference was insignificant (p=0.6346). The standard deviation of group A is fractionally higher than that of group B.

4. Discussion

In the past few decades in dentistry, there has been a wide array of materials like metal alloys, ceramics, and composites, for the fabrication of indirect restorations. Ceramic in dentistry is becoming popular, which has not only good mechanical properties but also excellent esthetics [9].

Several factors are to be considered while selecting the suitable restorative material for the procedure to provide optimal longevity [10]. The survival of the restorations depends upon various material factors. They are the marginal integrity of the material at the restorative-tooth interface, wear resistance, fracture resistance, modulus of elasticity, strength, dimensional stability, thermal conductivity, and biocompatibility of restorative material [11]. Adequate marginal adaptation is necessary to prevent microleakage, recurrent caries, and failure of the restoration. Direct and indirect restorations with inadequate marginal adaptation cause exposure of the dentin or base cement to the oral fluids and microbes. Eventually, the restoration may be vulnerable to microleakage and plaque accumulation that may lead to postoperative sensitivity, secondary caries, pulpal disease, and restoration failure. [12],[13] The horizon of CAD-CAM techniques modernized the indirect restorative procedures drastically. This reduced the chances of manual error and imperfections during the fabrication of restorations [14].

The study results revealed that the marginal adaptation of the CAD-CAM ceramic inlays was superior to that of heat pressed inlays. The difference was not significant statistically. Thus, the null hypothesis was accepted. The results were like earlier studies by Addi S et al. [5] who determined the marginal adaptation of lithium disilicate inlays. Another study [15] reported similar results while assessing the marginal adaptation of crowns. The improved marginal adaptation in CAD-CAM ceramic inlays was due to a reduced number of steps. Less number of steps decreases the risk of manual errors and imperfections during fabrication. Another reason was dimensional stability of material as there were no temperature changes. During fabrication of heat-pressed ceramic inlays temperature changes may result in dimensional changes during heating and cooling of ceramic.

Few earlier studies [4],[7] reported better marginal integrity with CAD-CAM fabricated ceramic inlays, and the difference was statistically significant. This difference could be due to the different study methodologies. One study [4] compared leucite reinforced ceramic with lithium disilicate ceramic inlays manufactured by CAD-CAM and heat-pressed technique. Another study [7] compared the two techniques using leucite reinforced ceramic material. Both studies employed a stereomicroscope for the determination of the marginal gap. In the present study, a scanning electron microscope was employed for its accuracy and a wider range of magnification.

On the contrary, Alajaji et al. [6] observed significantly better marginal adaptation with heat-pressed lithium disilicate ceramic material. The difference in the results could be due to the difference in fabrication and evaluation methods. In their study E4D dentist system scanner was employed for digital impression whereas 3Shape TRIOS was used in this study. Milling machine used in the current study was imes-icore milling device whereas in the previous study E4D three-axis milling machine and Tizian cut five-axis milling machine were used. The evaluation method employed in their study was micro-CT for internalfit and marginal fit whereas, in the present study, SEM was employed for marginal adaptation.

Apart from a reduced number of steps in CAD-CAM inlays, fabricated restorations can be luted in the same visit. Existing literature reported contradictory evidence regarding marginal adaptation achieved by both the techniques [16]. This could be due to differences in scanners, milling machines, and evaluation methods. As per existing evidence[17], video scanners are better than image scanners.

Thus, the 3Shape TRIOS scanner was employed in this study, which is a video scanner. Scanning electron microscopy allows direct examination of the specimens, but it requires the processing of specimens, which may result in irreversible changes in the specimens. Thus, marginal adaptation could not be studied after luting the restorations.

The acceptable clinical width of the marginal gap is controversial. Few authors [18],[19] reported that a marginal gap ranging from 100 to 120 µm is clinically acceptable to prevent degradation or dissolution of luting cement. According to many other studies, the marginal gap widths of 100 to 200 µm are considered clinically adequate for indirect restorations [20] – [22]. Significant measures were taken to eliminate observer bias by randomly coding the specimens during scanning electron microscopy. Another important measure taken for accuracy was measurement of marginal gaps at 12 specified points. These gap widths were averaged for each specimen. The study's limitation is that the scanning electron microscopy required sputter coating of the specimens which may result in desiccation of the specimens.

5. Conclusion

The method of fabrication did not significantly influence the marginal gap values of lithium disilicate ceramic inlays. The CAD-CAM ceramic inlays exhibited better marginal adaptation than heat-pressed ceramic inlays, though they did not differ significantly. All the ceramic inlays presented clinically acceptable marginal adaptation.

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b) Declaration

Conflict of Interest: Nil

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We certify that we have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript, to take public responsibility for it and have agreed to have our name listed as a contributor. We believe the manuscript represents valid work. Neither this manuscript nor one with substantially similar content under my/our authorship has been published or is being considered for publication elsewhere. We certify that all the data collected during the study is presented in this manuscript and no data from the study has been or will be published separately. We attest that, if requested by the editors, we will provide the data/information or will cooperate fully in obtaining and providing the data/ information on which the manuscript is based, for examination by the editors or their assignees. Financial interests, direct or indirect, that exist or may be perceived to exist for individual contributors in connection with the content of this paper have been disclosed in the cover letter. Sources of outside support of the project are named in the cover letter. We hereby transfer(s), assign(s), or otherwise convey(s) all copyright ownership, including all rights incidental thereto, exclusively to this journal, in the event that such work is published by the journal. The journal shall own the work, including 1) copyright; 2) the right to grant permission to republish the article in whole or in part, with or without fee; 3) the right to produce preprints or reprints and translate into languages other than English for sale or free distribution; and 4) the right to republish the work in a collection of articles in any other mechanical or electronic format. We give the rights to the corresponding author to make necessary changes as per the request of the journal, do the rest of the correspondence on our behalf and he/she will act as the guarantor for the manuscript on our behalf. All persons who have made substantial contributions to the work reported in the manuscript, but who are not contributors, are named in the Acknowledgment and have given me/us their written permission to be named. If we do not include an Acknowledgment that means we have not received substantial contributions from non-contributors and no contributor has been omitted.

References

[1] Kelly JR, Nishimura L, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 1996;75(1):18-32.
[2] Strub JR, Rekbow ED, Witkowski S. Computer aided design and fabrication of dental restorations. Current status and future possibilities. J Am Dent Assoc 2006;13(7):1289-96.
[3] Swift EJ, Sturdevany JR, Ritter AV. Class I and II indirect tooth colored restorations. In: Sturdevant JR (eds) Sturdevant's Art and science of Operative Dentistry. 5th ed. New Delhi, Elsevier; 2006. p603-622.
[4] Keshvad A, Hooshmand T, Asefzadeh F, Khalilinejad F, Alihemmati M, Van Noort R. Marginal gap, internal fit, and fracture load of leucite-reinforced ceramic inlays fabricated by CEREC inLab and hot-pressed techniques. J Prost 2011;20(7):535-540.
[5] Addi S, Hedayati-Khams A, Poya A, Sjögren G. Interface gap size of manually and CAD-CAM-manufactured ceramic inlays/onlays in vitro. J Dent 2002;30(1):53-58.
[6] Alajaji NK, Bardwell D, Finkelman M, Ali A. Micro-CT evaluation of ceramic inlays: comparison of the marginal and internal fit of five and three axis cam systems with a heat press technique. J Esthet Restor Dent 2017;29(1):49-58.
[7] Oz FD, Bolay S. Comparative evaluation of marginal adaptation and fracture strength of different ceramic inlays produced by CEREC Omnicam and heat-pressed technique. Int J Dent 2018;26(4):513-516.
[8] Rippe MP, Monaco C, Volpe L, Bottino MA, Scotti R, Valandro LF. Different methods for inlay production: Effect on internal and marginal adaptation, adjustment time, and contact point.Oper Dent 2017;42(4):436-444.
[9] Bottino MA, Campos F, Ramos NC, Rippe MP, Valandro LF, Melo RM. Inlays made from a hybrid material: Adaptation and bond strengths. Oper Dent 2015;40(3):83-91.
[10] Fernandes NA, Vally ZI, Sykes LM. The longevity of restorations - a literature review. Sout Afr Dent J 2015;70(9):410-413.
[11] Goldstein GR. The longevity of direct and indirect posterior restorations is uncertain and may be affected by a number of dentist-, patient-, and material-related factors. J Evid Based Dent Pract 2010;10(1):30-31.

[12] Homsy FR, Özcan M, Khoury M, Majzoub ZAK. Marginal and internal fit of pressed lithium disilicate inlays fabricated with milling, 3D printing, and conventional technologies. J Prosthet Dent 2018;119(5):783-790.
[13] David A. Graber and Ronald E. Goldstein. Cast ceramic systems and other alternatives. In: David A. Graber and Ronald E. Goldstein (eds) Porcelain and composite inlays and onlays. Chicago, Quintessence Publishing Co,1994. p104-116.
[14] Karin HN. The clinical challenge of achieving marginal adaptation in direct and indirect restorations. J Appl Oral Sci 2015;23(5):448-459.
[15] Melo Freire CA, Borges GA, Caldas D, Santos RS, Ignácio SA, Mazur RF.Marginal adaptation and quality of interfaces in lithium disilicate crowns - Influence of manufacturing and cementation techniques. Oper Dent 2017;42(2):185-195.
[16] Radek M, Danielle ML, Basel A. The marginal fit of E.max Press and E.max CAD lithium disilicate restorations: A critical review. Dent Mater J 2016;35(6):835-844.
[17] Jeong ID, Lee JJ, Jeon JH, Kim JH, Kim HY, Kim WC. Accuracy of complete-arch model using an intraoral video scanner: An in vitro study. J Prosthet Dent 2016;115(6):755–759.
[18] Holmes JR, Sulik WD, Holland GA, Bayne SC Marginal fit of castable ceramic crowns. J Prosthet Dent 1992;67(5):594-599.
[19] Mously HA, Finkelman M, Zandparsa R, & Hirayama H. Marginaland internal adaptation of ceramic crown restorations fabricated with CAD-CAM technology and the heat-press technique. J Prosthet Dent 2014;112(2):249-256.
[20] Hickel R, Peschke A, Tyas M, Mjör I, Bayne S, Peters M, Hiller KA, Randall R, Vanherle G, Heintze SD. FDI World Dental Federation: clinical criteria for the evaluation of direct and indirect restorations – update and clinical examples. Clin Oral Invest 2010;14(4):349-366.
[21] Wilson N, Lynch CD, Brunton PA, Hickel R, Meyer-Lueckel H, Gurgan S et.al. Criteria for the replacement of restorations: Academy of operative dentistry European Section. Oper Dent 2016;41(7):48-57.
[22] Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D et.al.Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies. J Prosth Dent 2018;121(4):1-11.