The effect of preparation designs and location of margins on the marginal gap of CAD/CAM ceramic onlays

Itsalapong Thainimit[1] Potjaman Totiam[1] Kornchanok Wayakanon[1]

Abstract

Objective: To evaluate the influence of preparation designs and the location of margins on the width of the marginal gaps of the CAD/CAM ceramic onlays.

Materials and Methods: Thirty-two sound human maxillary premolars were prepared and divided into four groups (n = 8), according to different preparation designs (remaining buccal wall thickness 1 mm (R1), 2 mm (R2) and 3 mm (R3) and occlusal overlay (R0)). Teeth were restored with CAD/CAM fabricated IPS e.max® CAD (CEREC MC XL, Dentsply Sirona). All ceramic restorations were cemented with a dual-cure resin cement (Panavia V5). The cement-line thickness was evaluated under a digital stereomicroscope along the margins of the restorations. The data was analyzed by 2-way ANOVA followed by the Tukey HSD test at P < 0.05

Results: Both preparation design and the location of margins had an influence on the width of the cement lines (P < 0.001). The R0 group had the statistically largest cement lines at the margins of the restorations compared to other groups (P < 0.001). For the location of margins, the width of the cement lines at the proximal margins (mesial and distal) was significantly larger than that of other surfaces (P < 0.001).

Conclusions: The preparation design and the location of margins had an influence on the marginal fit of the ceramic onlay restorations fabricated with the CAD/CAM technique.

Keywords: *CAD/CAM; ceramic; marginal gap; onlay*

[1]Department of Restorative Dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand, 65000

Introduction

Dental fillings are a routinely simply procedure to fix a small-sized tooth defect. However, in case of massive loss of tooth structure, an indirect restoration is required since it can provide better contour and occlusion as well as the chair timing economics.

An indirectly partial coverage restoration has become recently popular due to the vastly improvement of an adhesive system. A notable characteristic of the partial coverage restorations is the supragingival margin providing many advantages such as daily cleanable margin by patients and easily checking up by dentists.

Marginal discrepancy is an important criteria used in the clinical evaluation for fixed restorations. The importance of the marginal gap for clinical success of ceramic restorations has reported in several clinical trials.1-4 A restoration with large marginal discrepancy can lead to cement dissolution, microleakage, and plaque accumulation, which results in gingival inflammation and dental caries.5 Including ceramic onlay restorations, the margin integrity was associated with the longevity of the restorations. The inaccuracy in the marginal fit increased the part of cement subjected to oral environment leading to the degradation of dental cement and the discoloration of the restorations.6 McLean et al. suggested that the marginal discrepancies of the indirect restorations less than 120 µm are clinically acceptable.2

Currently, the CAD/CAM technology has become a popular in modern dental practice. The use of the CAD/CAM technology can not only make restorations in a single visit without impression procedure, but also control the quality and design by dentists. The most common material of all-ceramic restorations is lithium silicate glass-ceramics. An IPS e.max CAD® is one of the most popular lithium disilicate glass-ceramic for CAD/CAM applications. IPS e.max CAD® are composed of 40% lithium metasilicate crystals (Li2SiO3) 0.2-1.0 µm in a platelet shape. The IPS e.max CAD® is milled in a partially crystallized form in a "blue state".7 For marginal gap of CAD/CAM restorations, several studies reported the mean marginal gaps 80–85 µm in the partial coverage restorations.8, 9 However, the marginal adaptation of the indirect restorations was affected by preparation design.10-12 Currently, CAD/CAM milling machines use large diameter diamond rotary cutting instruments. The size of these diamond rotary cutting instruments may limit an ability of restoration milling, which the CAD/CAM milling machines are not able to reproduce the contour of the restorations in areas that are smaller than the diameter of the burs.13

The purpose of this study was to evaluate the influence of the preparation design and the location of margins on the width of the marginal gap of the IPS e.max CAD® onlays. The null hypothesis for this study was the different preparation designs and the location of margins had no influence on the width of the marginal gaps of the CAD/CAM ceramic onlays.

Material and method

Thirty-two sound human maxillary premolars without cracks, restorations or carious lesions, indicated extraction for the orthodontic treatment were selected in this study. Teeth were stored in 0.1% thymol solution at room temperature, and used within 3 months after extraction. After cleaning, teeth were selected within a similar size (9.5-10.5 mm bucco-lingual distance, 7.0-7.5 mm mesio-distal distance and 8.0-8.5 mm occluso-cervical distance). After that each tooth was examined to ensure that they were free of defects and cracks under a stereomicroscope (SZX-ILLD200; Olympus, Tokyo, Japan). All teeth were embedded in self-cured acrylic resin 3 mm below the cementoenamel junction.

Teeth were then randomly divided into 4 groups (N=8), according to different preparation designs (remaining buccal wall thickness 1, 2 and 3 mm and occlusal overlay). The groups of the experiment were listed in Table 1.

Table 1 The groups of the preparation design

Groups	**Experimental design**
R3	Remaining buccal wall thickness 3 mm
R2	Remaining buccal wall thickness 2 mm
R1	Remaining buccal wall thickness 1 mm
R0	Occlusal overlay

A high-speed handpiece with a 10-degree taper diamond bur were used. In all group, the MOD cavity was initially prepared. The depth of the occlusal cavity was 2 mm. The palatal wall of the occlusal cavity was 1-mm palatally from the central groove with 10-degree divergence. The angle of departures for the mesial and distal cavities were 120 degree. The gingival margins of the proximal cavities were gingivally deep 2 mm from the pulpal wall of the occlusal cavity. Both buccal walls and palatal walls of the proximal cavities were 10-degree divergence. The palatal cusp was reduced 2 mm following the incline plane to receive a butt joint margin.

For the buccal wall of the occlusal cavity, the remaining thickness of the buccal cusp was mainly considered. It was varied into 1, 2 and 3 mm from the buccal cusp tip. The buccal walls of the R1, R2 and R3 groups was 10-degree divergence. For the R0 group, the buccal cusp was reduced 2 mm following the incline plane to receive a butt joint margin (Fig. 1). The preparation depths were measured with a periodontal probe.

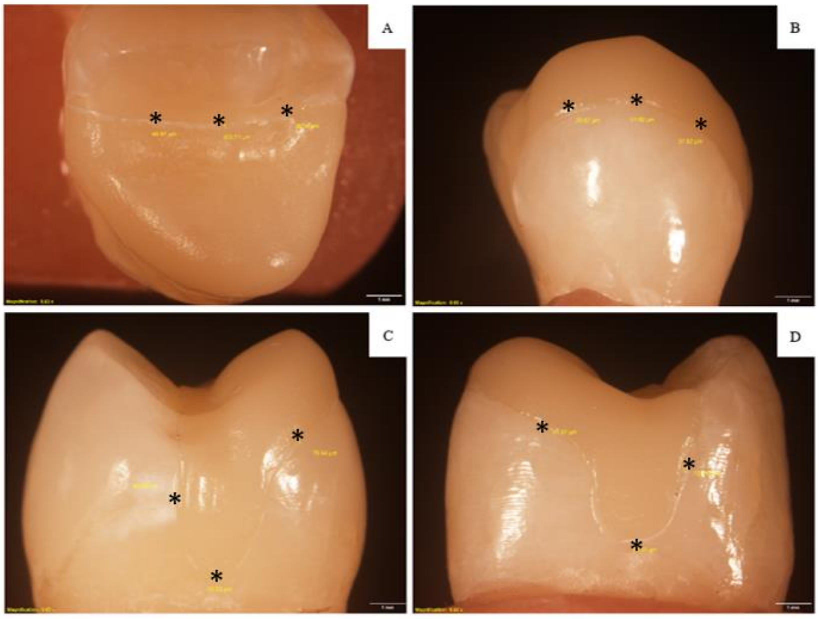

Figure 3 Measurement of the width of the cement line under the digital stereomicroscope (×12.5).
(A) occlusal surface, (B) Palatal surface, (C) Mesial surface and (D) Distal surface.
Asterisks: Reference point for measurement on each surfaces

After preparation, each sample was scanned with intraoral scanner (CEREC Omnicam, Dentsply Sirona) and designed for the restorations with the Computer-Aided Design (CAD) software (CEREC SW 4.5, Dentsply Sirona) with the similar procedure as the clinical process. The restorations were designed to receive 2 mm thickness at the palatal cusp to mimic the initial features (Fig. 2). The restorations were fabricated with the Computer-Aided Manufacturing (CAM) software (CEREC SW 4.5, Dentsply Sirona). All onlay restorations were milled from the lithium disilicate glass-ceramic IPS e.max® CAD (Ivoclar Vivadent, Schaan, Liechtenstein) in a milling units (CEREC MC XL, Dentsply Sirona). Heat treating step was performed after the milling process at temperature of 840oc for 30 minutes.

Before cementation, the restorations were checked under a stereomicroscope (SZX-ILLD200; Olympus, Tokyo, Japan) to prove without cracks and surface flaws. The restorations were tried in and adjusted on the prepared abutments and observed under the microscope.

The intaglio surfaces of the restorations were etched with 4.9% hydrofluoric acid (Porcelain Etch®, Ultradent, USA) for 20 seconds followed by thoroughly rinsed with water for 30 seconds and then oil-free air drying. The restorations were applied with the Clearfil ceramic primer plus for 5 seconds (following the instruction of Panavia V5, Kuraray Noritake. Dental Inc.).

The selective etch technique was applied along with the self-etch resin cement (Panavia V5, Kuraray Noritake. Dental Inc.). The selective-etched technique was performed with 37% phosphoric acid on enamel for 15 seconds. After that, it was rinsed with water for 30 seconds and prepared to achieve the moist dentin, followed by applied tooth primer with applicator brush for 20 seconds (Panavia V5, Kuraray Noritake. Dental Inc.). The self-etch resin cement (Panavia V5, Shade A2, Kuraray Noritake. Dental Inc.) was manipulated as recommended by the manufacturer and inserted into the intaglio surface of the restorations, which were seated in place using finger pressure. The excess cement was removed after tack cure with the light-curing unit (DemiTMPlus L.E.D., Kerr Co., USA) for 5 seconds on each surface. The cement was continuously cured with the light curing unit for 20 seconds on each surface. The surfaces of the restoration were finished and polished with ceramic polishing kit (Luster for silicate ceramics, Meisinger, USA). After cementation, all specimens were stored in water at 37oC for 7 days.

The measurements were performed under x25 magnification with a computerized digital image analysis system. This consisted of a stereomicroscope (Olympus SZX16; Olympus) attached to a Charge-Coupled Device (CCD) camera (Olympus DP73; Olympus, Tokyo, Japan) with a CellSens Standard software v. 1.18 (Olympus, Tokyo, Japan). The specimens were placed on the prepared silicone index to standardize the measurement. The live images of the marginal gaps were observed and captured (4800x3600 pixel). The measurement was performed on the captured static images. In each specimen, the thickness of the resin cement the margins (represented the width of the marginal gaps) of the restorations on each surface were measured (occlusal, palatal, mesial and distal). At the proximal surfaces, the middle of each walls was measured. For the buccal, lingual and occlusal surfaces, the middle point and the quarter points of each margins were measured. The locations of measurement were showed in figure 3. The thickness of the resin cement was measured for 12 areas on each sample. All restoration and measurement were performed by one operator.

The data was analyzed by Kolmogorov-Smirnov, two-way ANOVA with Tukey Honestly Significant Difference test (HSD) at $P < 0.05$.

Result

The mean values and standard deviations of the thickness of the resin cement at the margins of the restorations for all groups were shown in Table 2 and 3.

According to the preparation designs, the R0 group (104.99±31.60) had the largest width of the cement lines, which was significantly different from all other designs (P < 0.001). There was no significant difference in the width of the cement lines among the R1 (70.01±18.25), R2 (73.81±24.12) and R3 (62.25±18.27) (P > 0.05) (Table 2).

For the location of margins, the width of the cement lines at the proximal margins (mesial and distal) was significantly larger than that of other surfaces (P < 0.001) (Table 3).

Table 2 The width ± SD of the resin cement at the margin of the restorations in different preparation designs.

Preparation design	Width of the cement line (μm) ± SD
R3	62.25 ± 18.27^{A}
R2	73.81 ± 24.12^{A}
R1	70.01 ± 18.25^{A}
R0	104.99 ± 31.60^{B}

Superscript upper case characters represent statistically significant differences of the width of the cement line when compared among different preparation designs (*P* < 0.05).

Table 3 The width (±SD) of the resin cement at the margin of the restorations in different surfaces of tooth.

Tooth surfaces	Width of the cement line (μm) ± SD
Occlusal/Buccal	69.85 ± 25.22^{A}
Palatal	65.14 ± 24.81^{A}
Mesial	86.25 ± 27.17^{B}
Distal	89.81 ± 29.95^{B}

Superscript upper case characters represent statistically significant differences of the width of the cement line when compared among different tooth surfaces (*P* < 0.05).

Both preparation design and the location of margins had an individual influence on the width of the cement line (P < 0.001). However, the interaction between the preparation design and the location of margins had no effect on the width of the marginal gaps (P > 0.05) (Table 4).

Table 4 Two-way ANOVA for 2 main effects preparation designs and location of margins

	df	Sum of squares	Mean square	F value	*P* value
Preparation design	3	186333.936	62111.312	22.292	.000
Location of margin	3	69590.568	23196.856	8.325	.000
Preparation design and location of margin	9	38978.777	4330.975	1.554	.133
Error	160	445801.166	2786.257		
Total	176	2601753.323			

Discussion

This study investigated the width of the marginal gaps of the ceramic onlays at different location of margins in various preparation designs. The null hypothesis was rejected as the statistically significant differences ($P < 0.001$) were found among groups of different preparation designs or surfaces of teeth.

Natural human teeth were used in this study for investigating the width of the marginal gap of the IPS e.max onlays, which were fabricated by the CAD/CAM technique. The width of the marginal gap was measured after cementation with the resin cement. The excess cement was removed by the porcelain polishing kit before measurement. Therefore the width of the cement line in this study represented the gap width of the restorations.

The tooth preparation in each preparation design was performed according to the preparation guidelines for partial coverage restorations mentioned in the manufacturer's guideline.7

The results of this study showed that both preparation design and location of margins affected on the marginal fit of the restorations. Group R0 showed the largest cement line. The proximal surfaces also had the largest cement line. In the previous studies reported the marginal gap of CAD/CAM all ceramic onlays was ranged between 80-85 µm.5, 6 In this study, the marginal gap was between 62-105 µm. According to McLean and von Fraunhofer2, a marginal gap smaller than 120 µm was clinically acceptable. The width of the marginal gaps obtained in this study was clinically acceptable. However, other factors, such as type of resin cement, the method of restorative fabrication and the measuring technique, also affected the marginal discrepancy of the ceramic restorations.11 Hence all these factors should be considered in the clinical practices.12

The IPS e.max CAD has the shrinkage approximately 0.2% after the crystallization.6 The shrinkage occurs in all direction to the center of the material. The proximal surfaces showed the largest cement line. Within the calculation, the total height of the proximal wall was 6 mm. The shrinkage was 12 µm which should be the gap width at the gingival margin. However the measurement showed the gap width substantially larger than the calculation. This might be from the limitation of the machine such as the difficulty to access the proximal areas for scanning and the fabricating steps.11 In addition, the limitations of the designing software and the size of the cutting tools can result in the accuracy of the ceramic restorations from the CAD/CAM technique.12

For the preparation design, the width of the cement line on both buccal and palatal surfaces was largest in the R0 group (data not shown). This might be related to the complex geometry, with different angles and a higher material volume. Therefore, different cavity preparation designs were influenced to marginal fit of the restoration.12, 14-16 The cavity which has more angles might result in more chance of marginal discrepancy. In this study, the R0 group had the bucco-occlusal line angle on the occlusal cavity while other groups were the buccal wall with 10-degree divergence with no line angle.

The proximal margins had the largest cement line which might resulting of the complication of the restoration insertion. The marginal fit of the restoration on the proximal areas got an influence from the coronal part of the restoration. If there was some undercuts or asperities coronally to the gingival margin which impeded the passive seating, the gingival margin of the restoration frequently received the open margins. On the contrary, the buccal and lingual margins were at the coronal part of the cavity when insertion. They received small influences from other parts of the cavity when insertion.

Different methods for investigation the accuracy of the margins of the restorations had reported. There were a direct observation, 3D laser scanning, cross-sectioning replica, and micro-computed tomography. There was no consensus on which was the best method for assessment of the accuracy of the indirect restorations. The direct observation technique was one of the most commonly used methods to assess the marginal discrepancy.17 This is the economical method and less time consuming than other techniques.18

There were some limitations in this study. Selection of the area of measurement was restricted to the two-dimensional pictures. The similarity color of the resin cement and the tooth structure made it difficult to locate the area of cement lines. In the laboratory study, the finger pressure (78.5 N) was applied on the restoration when cementation while the clinical bite force on the cotton roll was approximately 137 N.19 However, an in vitro study had the advantage of providing standardized conditions with respect to the preparation design, technique, and experimental technique.

Conclusion

The preparation design and location of margins had an influence on the marginal fit of the ceramic onlay restorations fabricated with the CAD/CAM technique.

Acknowledgement

The research was supported by funding from the National Research Council of Thailand (NRCT). The authors would like to thank Dentsply Sirona (Thailand) Co. Ltd.

Reference

1. Sailer I., Feher A., Filser F., Gauckler L. J., Luthy H., H. HC. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. The International journal of prosthodontics. 2007;20(4):383-8.
2. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131(3):107-11.
3. Felton DA., Kanoy BE, Bayne SC, Wirthman GP. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent. 1991;65(3):357-64.
4. Karlsson S. The fit of Procera titanium crowns. An in vitro and clinical study. Acta Odontol Scand. 1993;51(3):129-34.
5. Demir N, Ozturk AN, Malkoc MA. Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography (micro-CT) technique. European journal of dentistry. 2014;8(4):437-44.
6. Abduo J, Sambrook RJ. Longevity of ceramic onlays: A systematic review. J Esthet Restor Dent. 2018;30(3):193-215.
7. Vivadent Ivoclar. Scientific Documentaion IPS e.max CAD. Liechtenstein. 2011.
8. Denissen H, Dozic A, van der Zel J, van Waas M. Marginal fit and short-term

clinical performance of porcelain-veneered CICERO, CEREC, and Procera onlays. J Prosthet Dent. 2000;84(5):506-13.
9. Stappert CF, Chitmongkolsuk S, Silva NR, Att W, Strub JR. Effect of mouth-motion fatigue and thermal cycling on the marginal accuracy of partial coverage restorations made of various dental materials. Dent Mater. 2008;24(9):1248-57.
10. Seo D, Yi Y, Roh B. The effect of preparation designs on the marginal and internal gaps in Cerec3 partial ceramic crowns. J Dent. 2009;37(5):374-82.
11. Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: a systematic review. J Prosthet Dent. 2013;110(6):447-54.e10.
12. Boitelle P, Mawussi B, Tapie L, Fromentin O. A systematic review of CAD/CAM fit restoration evaluations. J Oral Rehabil. 2014;41(11):853-74.
13. Renne W, McGill ST, Forshee KV, DeFee MR, Mennito AS. Predicting marginal fit of CAD/CAM crowns based on the presence or absence of common preparation errors. J Prosthet Dent. 2012;108(5):310-5.
14. Fonseca RB, Correr-Sobrinho L, Fernandes-Neto AJ, Quagliatto PS, Soares CJ. The influence of the cavity preparation design on marginal accuracy of laboratory-processed resin composite restorations. Clin Oral Investig. 2008;12(1):53-9.
15. Beuer F, Aggstaller H, Richter J, Edelhoff D, Gernet W. Influence of preparation angle on marginal and internal fit of CAD/CAM-fabricated zirconia crown copings. Quintessence international (Berlin, Germany : 1985). 2009;40(3):243-50.
16. Federlin M, Sipos C, Hiller KA, Thonemann B, Schmalz G. Partial ceramic crowns. Influence of preparation design and luting material on margin integrity--a scanning electron microscopic study. Clin Oral Investig. 2005;9(1):8-17.
17. Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: a literature review. Journal of prosthodontics: official journal of the American College of Prosthodontists. 2013;22(5):419-28.
18. Hamza TA, Ezzat HA, El-Hossary MM, Katamish HA, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/CAM systems. J Prosthet Dent. 2013;109(2):83-7.
19. Weaver JD, Johnson GH, Bales DJ. Marginal adaptation of castable ceramic crowns. J Prosthet Dent. 1991;66(6):747-53.

Correspondence Author

Itsalapong Thainimit
Degree: Doctor of Dental Surgery
Department of Restorative Dentistry,
Faculty of Dentistry, Naresuan University,
Phitsanulok, Thailand, 65000
Tel: 092-4659165
E-mail: itsalapong_dentnu@hotmail.com

ผลของการออกแบบโพรงฟันต่อความแนบบริเวณขอบของเซรามิกออนเลย์ที่ออกแบบและขึ้นรูปโดยคอมพิวเตอร์

อิสรพงษ์ ไทยนิมิต[1] พจมาลย์ โตเทียม[1] กรชนก วยัคฆานนท์[1]

บทคัดย่อ

วัตถุประสงค์: *เพื่อศึกษาผลของการออกแบบโพรงฟันและด้านของฟันต่อความกว้างของช่องว่างบริเวณขอบของเซรามิกออนเลย์ที่ออกแบบและขึ้นรูปโดยคอมพิวเตอร์โดยการวัดจากความหนาของซีเมนต์*

วัสดุและวิธีการ: *การศึกษานี้ใช้ฟันกรามน้อยของมนุษย์ที่ถูกถอนออกมาจำนวน 32 ซี่ โดยแบ่งกลุ่มการศึกษาออกเป็น 4 กลุ่ม (n=8) ตามการออกแบบโพรงฟันที่ต่างๆกัน (กลุ่ม R1-R3 ความหนาผนังโพรงฟันด้านแก้มเหลืออยู่ 1 2 และ 3 มม. ตามลำดับ และกลุ่ม R0 โพรงฟันแบบโอเวอร์เลย์) จากนั้นฟันที่กรอเตรียมโพรงฟันจะได้รับการบูรณะด้วยก้อนเซรามิกสำหรับระบบคอมพิวเตอร์ (IPS e.max® CAD) และทำการยึดติดด้วยเรซินซีเมนต์ (Panavia V5) จากนั้นนำไปประเมินความกว้างของช่องว่างบริเวณขอบของวัสดุบูรณะภายใต้กล้องสเตอริโอไมโครสโคป ค่าที่วัดได้จะนำมาวิเคราะห์ข้อมูลทางสถิติด้วยการทดสอบความแปรปรวนแบบสองทาง และเปรียบเทียบความแตกต่างระหว่างกลุ่มที่ระดับนัยสำคัญ 0.05*

ผลการศึกษา: การออกแบบโพรงฟันและด้านของฟันมีผลต่อความกว้างของซีเมนต์บริเวณขอบของวัสดุบูรณะ *(P < 0.001)* โดยกลุ่ม *R0 จะมีความกว้างของซีเมนต์บริเวณขอบมากที่สุดอย่างมีนัยสำคัญทางสถิติ (P < 0.001) และความกว้างของซีเมนต์บริเวณขอบของวัสดุบูรณะที่ด้านประชิดฟันจะมีความกว้างมากกว่าด้านอื่นๆอย่างมีนัยสำคัญทางสถิติ (P < 0.001)*

สรุป: *การออกแบบโพรงฟันและด้านของฟันมีผลต่อความแนบบริเวณขอบของเซรามิกออนเลย์ที่ขึ้นรูปด้วยระบบคอมพิวเตอร์*

คำสำคัญ: *แคด/แคม; เซรามิก; ช่องว่างบริเวณขอบ; ออนเลย์*

[1]ภาควิชาทันตกรรมบูรณะ คณะทันตแพทยศาสตร์ มหาวิทยาลัยนเรศวร อำเภอเมือง จังหวัดพิษณุโลก 65000