

Marginal and internal fit of nano-composite CAD/CAM restorations

So-Hyun Park¹,
Yeon-Jee Yoo², Yoo-
Jin Shin², Byeong-
Hoon Cho², Seung-Ho
Baek^{2*}

¹Seoul National University Dental Hospital, Seoul, Korea

²Department of Conservative Dentistry, Seoul National University School of Dentistry and Dental Research Institute, Seoul, Korea

Objectives: The purpose of this study was to compare the marginal and internal fit of nano-composite CAD-CAM restorations. **Materials and Methods:** A full veneer crown and an mesio-occluso-distal (MOD) inlay cavity, which were prepared on extracted human molars, were used as templates of epoxy resin replicas. The prepared teeth were scanned and CAD-CAM restorations were milled using Lava Ultimate (LU) and experimental nano-composite CAD/CAM blocks (EB) under the same milling parameters. To assess the marginal and internal fit, the restorations were cemented to replicas and were embedded in an acrylic mold for sectioning at 0.5 mm intervals. The measured gap data were pooled according to the block types and measuring points for statistical analysis. **Results:** Both the block type and measuring point significantly affected gap values, and their interaction was significant ($p = 0.000$). In crowns and inlays made from the two blocks, gap values were significantly larger in the occlusal area than in the axial area, while gap values in the marginal area were smallest ($p < 0.001$). Among the blocks, the restorations milled from EB had a significantly larger gap at all measuring points than those milled from LU ($p = 0.000$). **Conclusions:** The marginal and internal gaps of the two nano-composite CAD/CAM blocks differed according to the measuring points. Among the internal area of the two nano-composite CAD/CAM restorations, occlusal gap data were significantly larger than axial gap data. The EB crowns and inlays had significantly larger gaps than LU restorations. (*Restor Dent Endod* 2016;41(1):37-43)

Key words: Internal gap; Lava ultimate; Marginal gap; Nano-composite CAD/CAM blocks

Received August 25, 2015;
Accepted November 27, 2015.

Park SH, Yoo YJ, Shin YJ, Cho BH,
Baek SH

*Correspondence to

Seung-Ho Baek, DDS, PhD.
Professor, Department of
Conservative Dentistry, Seoul
National University School of
Dentistry and Dental Research
Institute, 101 Daehag-ro, Jongro-
gu, Seoul, Korea 03080
TEL, +82-2-2072-3951; FAX, +82-2-
2072-3859; E-mail, shbaek@snu.
ac.kr

Introduction

Computer aided design/computer aided manufacturing (CAD/CAM) systems have rapidly gained popularity during the last few decades. CAD/CAM systems predominantly utilize ceramic materials for their esthetic qualities, surface finish, and long-term durability. However, recently, composite resin CAD/CAM blocks have become available, opening up a wider range of potential materials.

Composite resin CAD/CAM blocks can be fabricated under controlled conditions offering the highest attainable quality. Composite CAD/CAM blocks are polymerized under standardized parameters at high temperatures and pressures to form hybrid, nano-filled and nano-hybrid composite resins.¹ Therefore, the physical and optical color stability are higher compared to conventionally fabricated indirect composite resin restorations.² Additionally, restorations produced from composite resin CAD/CAM blocks are easier to repair than restorations made from ceramic CAD/CAM blocks.^{1,3,4}

Several composite resin CAD/CAM block materials are available for dental restorations. Lava ultimate (LU, 3M ESPE, St. Paul, MN, USA), a resin nano-ceramic (RNC) material, was introduced as a nano-composite CAD/CAM block consisting of a highly cured resin matrix with embedded nano-ceramic particles. It contains filler mixtures of silica particles (20 nm), zirconia nanomers (4 - 11 nm) and aggregated clusters (0.6 - 1.0 μm) with a total filler loading of approximately 80 wt%.⁵ An experimental nano-hybrid composite CAD/CAM block (EB, Vericom Co., Anyang, Korea), which contains nano-filler (10 - 20 nm) which agglomerate as micro-sized ceramic cluster filler (1 - 5 μm), micro-hybrid particle (0.5 - 1.0 μm), and nano-silica filler (10 - 20 nm).

Marginal adaptation, together with adequate preparation design or cementation, is one of the main factors that determine the long-term success of indirect esthetic restorations. Marginal discrepancies in indirect restorations can increase the risk of cement dissolution and microleakage.⁶⁻⁹ *In vitro* studies reported mean marginal gaps of 50 to 60 μm in full veneer crowns and 150 to 168 μm in mesio-occluso-distal (MOD) inlays fabricated using ceramic CAD/CAM materials.¹⁰ However, few data are available concerning the marginal fit of composite resin CAD/CAM restorations. Therefore, this study sought to investigate the marginal and internal fit of nano-composite CAD/CAM restorations by using LU and EB nanocomposite CAD/CAM blocks with a full veneer crown and a mesio-occluso-distal (MOD) inlay with a one-cusp-capping design. The null hypothesis was that there would be no differences in marginal and internal gaps among the CAD/CAM blocks regardless of the measuring point.

Materials and Methods

Specimen preparation

The protocol of this study was approved by the Institutional Review Board of Seoul National University Dental Hospital, Seoul, Korea (CRI14020). Two caries-free extracted human molars were cleaned and stored under moist conditions at room temperature. The teeth were embedded in yellow stone (Snow rock dental stone ND, DK MunGyo Corp., Gimhae, Korea). One was prepared as a full veneer crown with the following dimensions: axial reduction of 1 mm and occlusal reduction of 1.5 mm with a rounded shoulder margin. The other tooth was prepared with an MOD-geometry inlay cavity 2 mm in depth and isthmus width. The finishing lines on the mesial and distal sides of the rounded boxes were 1 mm above the cemento-enamel junction. Then, the mesiobuccal cusp was reduced by 2 mm for cusp capping following the anatomical form of the occlusal surface. All marginal preparations were finished with a rounded shoulder design. All surfaces were

smoothed and all internal line angles were rounded with fine diamond burs (Mani dia bur TR-26F, Mani Inc., Tochigi, Japan) under a dental surgical microscope (OPMI Pico, Carl Zeiss Surgical GmbH, Oberkochen, Germany) (Figures 1a and 1b). After the preparation, the epoxy resin replicas (Struers, Copenhagen, Denmark) of each restoration design were fabricated.

The replicas were coated with anti-reflection powder (VITA CEREC Powder, VITA Zahnfabrik, Bad Säckingen, Germany), and the optical impression was taken using an intraoral camera (CEREC Bluecam, Sirona Dental Systems GmbH, Bensheim, Germany). The images were transferred to CEREC software version 4.00 and used to design the restorations. The parameters for the spacers (luting space) and adhesive gaps were set to 140 μm and 20 μm , respectively, according to the manufacturer recommended settings for LU. Ten crowns and ten inlays were milled with either of LU and EB.

The milled restorations were inspected for any defects, and placed in the replica to assess fitness. All restorations were cleaned and sandblasted with aluminum oxide (grain size $\leq 50 \mu\text{m}$ at 30 psi \pm 2 psi) until the entire bonding surface had a matte finish, according to the manufacturers' instructions. After removing the sand, adhesive (Scotchbond Universal Adhesive, 3M ESPE) was applied to the bonding surface and agitated for 20 seconds. After that, uniform layer of cement material (RelyX Ultimate Clicker Adhesive Resin Cement, 3M ESPE) was applied and the restorations were set completely to the restoration.

Gap measurement

After cementation, the specimens were examined under a dental surgical microscope ($\times 40$, OPMI pico, Carl Zeiss) and were photographed with a digital camera to assess the external marginal gap at selected points. Then, each specimen was embedded in an acrylic resin block, and sectioned bucco-lingually and mesio-distally to obtain 10 segments using a water-cooled low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) 0.5 mm in thickness (Figures 1c and 1d). A total of 20 cross-section images from the both sides of sectioned segment were obtained for each specimen, and the internal gap was measured at 10 points along each internal cavity outline, and at 3 points in each transitional area. Gap measurement was performed by determining the shortest distance between the foot of the perpendiculars connecting the tangent of the abutment (replica)-restoration interfaces.

Statistical analyses

The collected gap data were pooled according to the measuring points (occlusal, axial, transitional, or marginal) in both the crown and inlay, while the data at the occlusal,

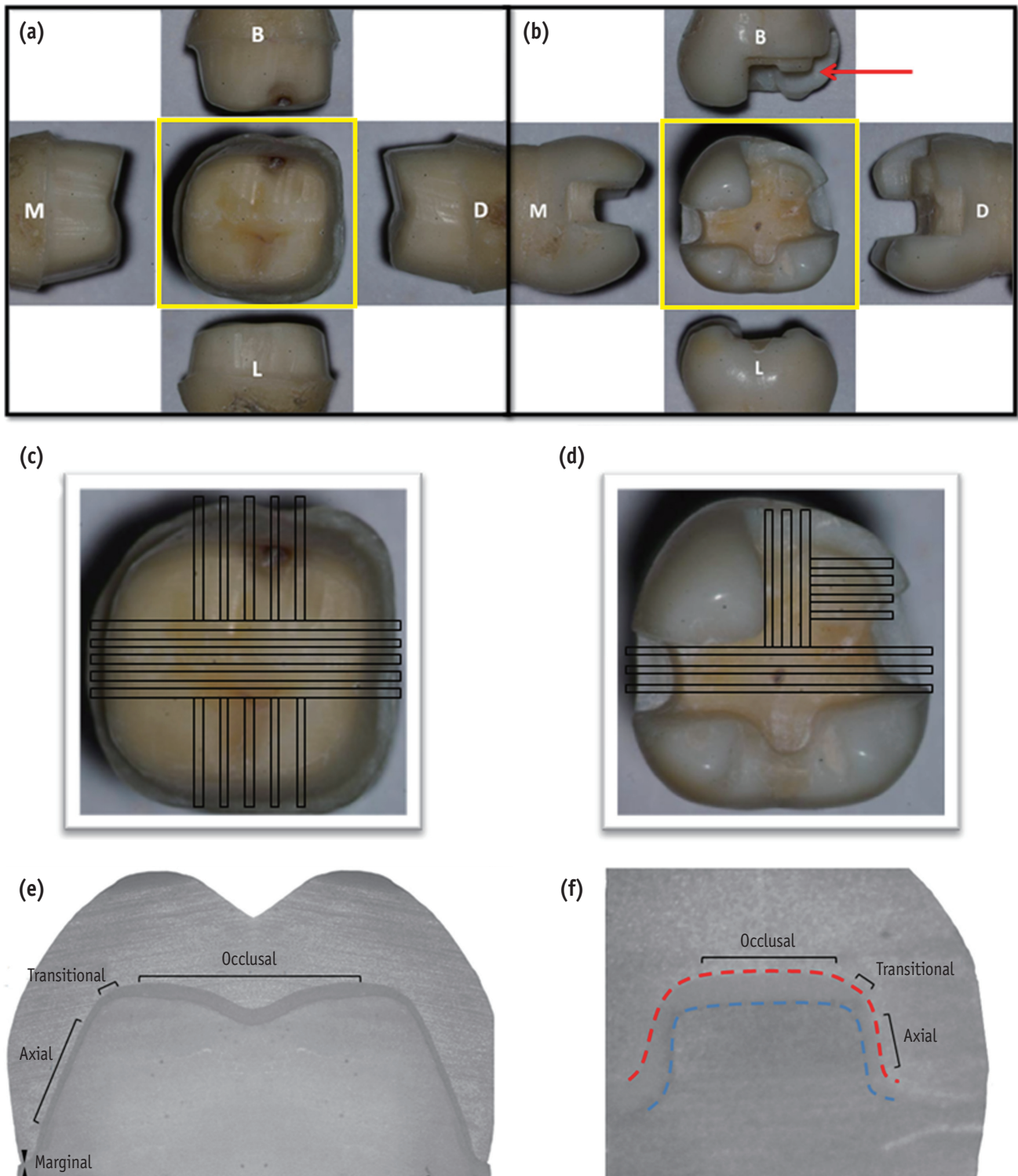


Figure 1. (a, b) Preparation design of nano-composite CAD/CAM restorations. (a) full crown and (b) mesio-occluso-distal inlay with a cusp capping; (c, d) Occlusal view from the yellow boxes of (a) and (b) were used to illustrate the representative diagrams showing the sectioned segments (black boxes) obtained from each specimen of (c) full crowns and (d) inlays; (e, f) Representative diagram showing the measuring points of the internal marginal fit of (e) the full crown and (f) the cusp capping area of the inlay (red arrow in (b)). M, mesial view; D, distal view; B, buccal view; L, lingual view.

axial and transitional points of the cusp capping area in inlays were additionally organized (Figures 1e and 1f). All gap measurements of each preparation design were separately analyzed with two-way analysis of variance (ANOVA) using the type of CAD/CAM block and the measuring point as the main factors, followed by Tukey's *post-hoc* comparisons. The significance level was set at $\alpha = 0.05$. All statistical analyses were performed by using SPSS 21.0 (SPSS Inc., Chicago, IL, USA).

Results

Gap data of both crowns and inlays are presented in Tables 1 and 2, respectively. Two-way ANOVA suggested that the two main factors (the type of CAD/CAM block and the measuring point) and their interaction were significant in both crowns and inlays ($p = 0.000$). Gap data of CAD/CAM restorations from both blocks showed the occlusal gap to be the largest among the measuring

Table 1. Gap measurement of crowns made of two CAD/CAM blocks according to the measuring points (Unit, μm ; mean \pm standard deviation)

		Block type	
		Experimental block	Lava ultimate
Measuring point	Occlusal	252.92 \pm 12.51 ^{Aa}	195.57 \pm 6.92 ^{Ba}
	Axial	104.82 \pm 7.07 ^{Bc}	123.63 \pm 8.36 ^{Ab}
	Transitional	162.87 \pm 8.89 ^{Ab}	111.73 \pm 7.16 ^{Bc}
	Marginal	57.65 \pm 4.10 ^{Ad}	50.18 \pm 3.39 ^{Bd}
Overall		144.57 \pm 73.48 ^A	120.42 \pm 51.98 ^B

Values with the same uppercase superscript letters within the same row are not significantly different between the two composite resin CAD/CAM blocks ($p > 0.05$).

Values with the same lowercase superscript letters within the same column are not significantly different among the measuring points ($p > 0.05$).

Table 2. Gap measurement of inlays made of two CAD/CAM blocks according to the measuring points (Unit, μm ; mean \pm standard deviation)

		Block type	
		Experimental block	Lava ultimate
Whole cavity	Occlusal	219.76 \pm 6.52 ^{Aα}	175.44 \pm 5.85 ^{Bα}
	Axial	142.47 \pm 9.05 ^{AB}	111.05 \pm 5.29 ^{Bβ}
	Transitional	138.64 \pm 11.25 ^{Aχ}	102.78 \pm 8.23 ^{Bχ}
Mesio-occluso-distal cavity	Occlusal	222.50 \pm 10.38 ^{Aa}	164.34 \pm 6.29 ^{Bb}
	Axial	144.33 \pm 13.97 ^{Ad}	131.34 \pm 6.60 ^{Bc}
	Transitional	118.86 \pm 5.92 ^{Af}	103.20 \pm 6.98 ^{Bd}
Measuring point Cusp capping area	Occlusal	216.49 \pm 10.38 ^{Ab}	186.54 \pm 10.52 ^{Ba}
	Axial	140.60 \pm 8.86 ^{Ae}	90.76 \pm 8.35 ^{Be}
	Transitional	173.78 \pm 13.38 ^{Ac}	102.33 \pm 9.33 ^{Bd}
Marginal		55.27 \pm 6.40 ^{Ag}	48.72 \pm 4.07 ^{Bf}
Overall		149.76 \pm 58.36 ^A	120.82 \pm 46.72 ^B

Values with the same uppercase superscript letters within the same row are not significantly different between the two composite resin CAD/CAM blocks ($p > 0.05$).

Values with the same lowercase superscript letters within the same column are not significantly different among the measuring points ($p > 0.05$).

Values with the same greek superscript letters within the same column of the 'whole cavity' row are not significantly different among the measuring points ($p > 0.05$).

points and the marginal gap to be the smallest in the two preparation designs ($p = 0.000$). EB restorations showed a significantly larger gap at all measuring points, including the cusp capping area of inlays ($p < 0.001$), except the axial walls of crowns ($p > 0.05$). In EB inlays, gap data at the transitional area were significantly larger in the cusp capping area than in other cavity areas ($p = 0.000$), while LU inlays showed similar values in the transitional areas of the internal cavity outlines ($p > 0.05$).

Discussion

The aim of this study was to examine and compare the external and internal marginal gap of the two different nano-composite CAD/CAM blocks in different restoration designs. We found that the nano-composite CAD/CAM block type and measuring point had a significant influence on external and internal marginal fit of CAD/CAM restorations in both preparation designs. Between the blocks, the restorations milled from EB had a significantly larger gap at all measuring points compared to those milled from LU. In crowns and inlay restorations made from the two blocks, gap data were significantly larger in the occlusal than in the axial area, while those in the marginal area were the smallest.

There are several methods for evaluating the fit of CAD/CAM restorations. Marginal fit can be assessed using microphotography and light microscopy, silicone replicas of the fit between the abutment and the restoration, silicon weight and density evaluation, virtual 3D analysis with a noncontact scanner and specific software, and micro-computerized tomographic (micro-CT) technology with no impression of cementation.¹¹⁻¹⁷ In this study, the tooth-restoration spacing was measured using light microscopy after cementation and sectioning was done. This nonconservative method has some shortcomings, such as the limited number of sections and the risk of specimen loss during sectioning. However, it is advantageous for evaluating both external and internal marginal fit in the same specimen after cementation, which is not easy with the micro-CT technique because external and internal gap data are usually combined to calculate overall mean values. Additionally, it is possible to evaluate the actual gap with various levels of microscopic magnification, which is not possible when using other methods.

Most authors agree that 120 μm of indirect restoration could be a clinically acceptable scale for external marginal spacing, but the criteria for internal fit have not yet been determined.^{1,3,18-23} A systematic review of external and internal marginal fit for ceramic indirect restorations was carried out by Boitelle *et al.*¹² They reviewed 230 articles, and 90 articles were selected for data analysis, including various materials such as zirconia, feldspathic ceramic, leucite-reinforced feldspathic ceramics, and CAD/CAM

systems. They concluded that the external marginal gap ranged from 39.1 to 201.0 μm and the internal marginal gap ranged between 23 and 230 μm . In terms of the marginal fit of CEREC systems, Nakamura *et al.* reported that the external marginal fit of all CAD/CAM ceramic crowns varied from 30 to 108 μm according to the pre-set milling value.¹³

Little is known about the marginal fit of the restorations with nano-composite CAD/CAM blocks. There have been two studies dealing with nano-composite CAD/CAM block Paradigm MZ 100 (3M ESPE).^{24,25} A study examining the marginal fit of crowns with three different margin designs by Tsitrou *et al.* reported an external marginal fit of 77 to 105 μm in CAD/CAM crowns fabricated with Paradigm MZ100 using a replica and sectioning method.²⁴ Another study by Akbar *et al.* reported that the mean marginal gap ranged from 46.0 to 65.9 μm in composite CAD/CAM crowns.²⁵

The gap difference between the two blocks was even higher in complicated abutment designs, such as the transitional gap of the cusp capping area in MOD inlays. This result is in accordance with previous researches reporting that a retentive preparation design (including cusp capping) resulted in a larger mean gap.^{26,27} The larger gap in the transitional area indicates a poor fit of the cusp capping area in EB inlays. Improper fit of the restoration in such internal structure could not be detected if the external marginal fit is acceptable. Moreover, most capped cusps are functional cusps. The tendency toward a larger gap in such areas may result in thinner restoration thickness, and may increase the risk of restoration fracture under occlusal forces. In clinical situations, extra care is required during the cementation procedure and resin cements should be used to strengthen and support the restoration.

In this results, the internal gap of the restorations differed according to the measuring point. The occlusal gap of both crowns and inlays was larger than the preset parameter, while the axial gaps were not. This regional discrepancy is in accordance with previous studies regardless of the CAD/CAM block materials, experiment method, or preparation designs, which implies a possible consequence of milling process and restoration-designing software of the CAD/CAM system.^{10,26-28} Aside from this regional discrepancy, such milling software might be a main cause of the differences between the two blocks. Both tested blocks were milled using the same settings in an LU-specific program originally pre-built using CEREC software. CEREC software is a closed system, and thus the milling program is not shared with other blocks. Different milling conditions might produce different results. These data could be utilized to determine the milling characteristics of the tested blocks and further to their clinical performance. In-depth investigation of mechanical properties and milling conditions as well as clinical study are required to

determine the clinical relevance of nano-composite CAD/CAM restorations.

Conclusions

Within the limitations of this study, the type of CAD/CAM block and the measuring point significantly affected the marginal and internal fit of the restorations. EB restorations had significantly larger gaps than LU restorations. Occlusal gap data from the two composite resin CAD/CAM blocks were the largest, while marginal values were the smallest.

Acknowledgement

This study was supported financially by the Ministry of Trade, Industry, & Energy and the Korea Institute for Advancement of Technology through the Project Supporting Core Institutions in Metropolitan Area (grant no. A00690007).

Orcid number

Yeon-Jee Yoo, 0000-0002-3931-7668

Byeong-Hoon Cho, 0000-0001-9641-5507

Seung-Ho Baek, 0000-0003-2594-2283

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

References

1. Nguyen JF, Migonney V, Ruse ND, Sadoun M. Resin composite blocks via high-pressure high-temperature polymerization. *Dent Mater* 2012;28:529-534.
2. Stawarczyk B, Sener B, Trottmann A, Roos M, Özcan M, Hämmerle CH. Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ceramic: effect of storage media, duration, and subsequent polishing. *Dent Mater J* 2012;31:377-383.
3. Lauvahutanon S, Takahashi H, Shiozawa M, Iwasaki N, Asakawa Y, Oki M, Finger WJ, Arksornnukit M. Mechanical properties of composite resin blocks for CAD/CAM. *Dent Mater J* 2014;33:705-710.
4. Rocca GT, Bonnafous F, Rizcalla N, Krejci I. A technique to improve the esthetic aspects of CAD/CAM composite resin restorations. *J Prosthet Dent* 2010;104:273-275.
5. 3M ESPE M: Lava Ultimate CAD/CAM restorative-technical product profile. 2011. Available from: http://www.d-way.cz/data/product/13/23/files/Lava_Ult_TPP.pdf (updated 2016 Jan 2).
6. Molin M, Karlsson S. The fit of gold inlays and three ceramic inlay systems. A clinical and *in vitro* study. *Acta Odontol Scand* 1993;51:201-206.
7. Wang WC, McDonald A, Petrie A, Setchell D. Interface dimensions of CEREC-3 MOD onlays. *Eur J Prosthodont Restor Dent* 2007;15:183-189.
8. Martin N, Jedynekiewicz NM. Interface dimensions of CEREC-2 MOD inlays. *Dent Mater* 2000;16:68-74.
9. Sjögren G. Marginal and internal fit of four different types of ceramic inlays after luting. An *in vitro* study. *Acta Odontol Scand* 1995;53:24-28.
10. Reich S, Gozdowski S, Trentzsch L, Frankenberger R, Lohbauer U. Marginal fit of heat-pressed vs. CAD/CAM processed all-ceramic onlays using a milling unit prototype. *Oper Dent* 2008;33:644-650.
11. Baig MR, Tan KB, Nicholls JI. Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system. *J Prosthet Dent* 2010;104:216-227.
12. Boitelle P, Mawussi B, Tapie L, Fromentin O. A systematic review of CAD/CAM fit restoration evaluations. *J Oral Rehabil* 2014;41:853-874.
13. Nakamura T, Dei N, Kojima T, Wakabayashi K. Marginal and internal fit of Cerec 3 CAD/CAM all-ceramic crowns. *Int J Prosthodont* 2003;16:244-248.
14. Krasanaki ME, Pelekanos S, Andreiotelli M, Koutayas SO, Eliades G. X-ray microtomographic evaluation of the influence of two preparation types on marginal fit of CAD/CAM alumina copings: a pilot study. *Int J Prosthodont* 2012;25:170-172.
15. Pelekanos S, Koumanou M, Koutayas SO, Zinelis S, Eliades G. Micro-CT evaluation of the marginal fit of different In-Ceram alumina copings. *Eur J Esthet Dent* 2009;4:278-292.
16. Rungruangnunt P, Kelly JR, Adams DJ. Two imaging techniques for 3D quantification of pre-cementation space for CAD/CAM crowns. *J Dent* 2010;38:995-1000.
17. Matta RE, Schmitt J, Wichmann M, Holst S. Circumferential fit assessment of CAD/CAM single crowns-a pilot investigation on a new virtual analytical protocol. *Quintessence Int* 2012;43:801-809.
18. Fonseca JC, Henriques GE, Sobrinho LC, de Góes MF. Stress-relieving and porcelain firing cycle influence on marginal fit of commercially pure titanium and titanium-aluminum-vanadium copings. *Dent Mater* 2003;19:686-691.
19. Weaver JD, Johnson GH, Bales DJ. Marginal adaptation of castable ceramic crowns. *J Prosthet Dent* 1991;66:747-753.
20. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an *in vivo* technique. *Br Dent J* 1971;131:107-111.
21. Brunthaler A, König F, Lucas T, Sperr W, Schedle A. Longevity of direct resin composite restorations in posterior teeth. *Clin Oral Invest* 2003;7:63-70.
22. Yu H, Wegehaupt FJ, Wiegand A, Roos M, Attin T, Buchalla W. Erosion and abrasion of tooth-colored restorative materials and human enamel. *J Dent* 2009;37:913-922.

23. Stawarczyk B, Egli R, Roos M, Ozcan M, Hämmerle CH. The impact of *in vitro* aging on the mechanical and optical properties of indirect veneering composite resins. *J Prosthet Dent* 2011;106:386-398.
24. Tsitrou EA, Northeast SE, van Noort R. Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM. *J Dent* 2007;35:68-73.
25. Akbar JH, Petrie CS, Walker MP, Williams K, Eick JD. Marginal adaptation of Cerec 3 CAD/CAM composite crowns using two different finish line preparation designs. *J Prosthodont* 2006;15:155-163.
26. Kim JH, Cho BH, Lee JH, Kwon SJ, Yi YA, Shin Y, Roh BD, Seo DG. Influence of preparation design on fit and ceramic thickness of CEREC 3 partial ceramic crowns after cementation. *Acta Odontol Scand* 2015;73:107-113.
27. 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;37:374-382.
28. Nam SJ, Yoon MJ, Kim WH, Ryu GJ, Bang MK, Huh JB. Marginal and Internal Fit of Conventional Metal-Ceramic and Lithium Disilicate CAD/CAM Crowns. *Int J Prosthodont* 2015;28:519-521.