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Marginal Fit Comparison of Crowns Fabricated with Two CAD/CAM Systems

A THESIS

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Of the Requirements

For the Degree of

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By

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April 24, 2020

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Abstract

Objective: To compare marginal fit of lithium-disilicate (LD/IPS e.max CAD) and leucite-reinforced (LR/IPS empress CAD) crowns fabricated with two different chairside CAD/CAM systems: CEREC MCXL and PlanMill 40. H01 is: there will be no difference in marginal fit between crowns fabricated with CEREC MCXL and PlanMill 40. H02 is: there will be no difference in marginal fit between LD and LR CAD crowns.

Methods: Extracted human mandibular molar (#19) was prepared following Ivoclar Vivadent guidelines for full-coverage posterior crown including: rounded internal line angles with preservation of occlusal anatomy, axial and occlusal reduction of at least 1 mm with modified shoulder of at least 1 mm slightly above the CEJ level. The preparation height was 4 mm with taper of about 6.9 degree. The prepared molar was secured in a typodont (M-860). Twelve digital impressions were obtained by each acquisition systems: CEREC Omnicam and Planmeca PlanScan. Each scan was used twice: to design and fabricate one LD and one LR crowns utilizing factory default settings. LD crowns were crystalized using a dental lab furnace, Programat P700 as per manufacturer's instructions. Marginal gap measurements were accomplished by one calibrated evaluator utilizing a digital microscope, Hirox KH-8700/x150 magnification. Crown specimens were randomly assigned a numeric code and occlusal surfaces masked with wax to blind the evaluator. 16 locations, evenly distributed along the molar margin were marked as sites to perform gap measurements. Three measurements were made at each site and an average of these three was mean marginal fit for that point. In total, 48 measurements were collected with 16 mean marginal fits per crown specimen. Mean marginal gap and standard deviation (SD) for each group were calculated. Statistical analysis: Kruskal-Wallis Test (p=0.05)

Results:

No statistical differences were found in marginal fit between both CAD/CAM systems. No statistical differences were found in marginal fit between both tested materials. Failed to reject H01 and H02.

Conclusion:

Under the conditions of this study, there was no difference in marginal fit between CEREC MCXL and PlanMill 40 CAD/CAM systems for both: LD and LR ceramic materials.

Manuscript

Introduction

In recent years, the application of CAD/CAM (computer-aided design/computer-aided manufacturing) technology in dentistry has become a common fabrication technique for dental restorations[1]. Digital technology is considered to provide high quality prosthesis in terms of esthetics and durability and offers a unique opportunity of one visit dental appointments including tooth preparation, crown design, fabrication and delivery[2]. Current CAD/CAM systems comprise three components: scanning, design and manufacturing. All three components may influence the marginal fit during fabrication of a CAD/CAM crowns. In terms of scanning, several studies have shown that, focusing on single preparations or fixed partial dentures, digital impressions yield a high accuracy[3-7]. In terms of design and manufacturing, little is known about how CAD/CAM strategies might influence the marginal fit of fabricated restorations that are machined out of a material block.

The factors that influence the accuracy of the design and the milling process are: CAD/CAM software parameter settings, milling instrument geometries, such as diameter, length and type of instrument, and the embedded technology of CAM units, composed of axis motor and position resolution, milling repeatability and spindle speed[8].

When comparing two CAD/CAM milling machines, the number of cutting paths or axes is important: higher number of axes offers more precise and detailed milling. Usually CAM milling mechanism function following 3-4 or five cutting axes. They can be linear or rotary[9] (Figure 1).

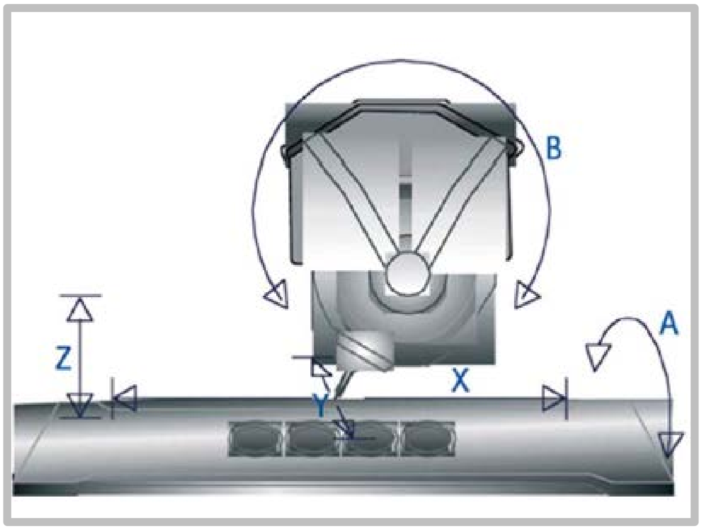

Figure 1.
Embedded mechanism of CAM unit. Three linear working axes in X, Y, Z plans and 2 rotary, where A: tension bridge, B: milling spindle

-

CEREC MCXL and PlanMill 40 are comparable in terms of the technical criteria as both systems use three axis for milling and two spindles. The additional 4th axis in CEREC MCXL is only used during the initialization phase for gauging and block check [3].

The accuracy of marginal fit is the characteristic most closely related to the longevity of restoration[10] and the imperfections at the margins can lead to the inflammation of gingival tissue. Increased marginal gap size can result in plaque accumulation and microleakage. In several clinical studies, a high rate of secondary caries has been attributed to marginal deficiency[11-14].

Many authors have tried to determine the range of clinically acceptable marginal gap. Christensen reported that the range for subgingival margins was 34 to 119 µm and 2 to 51 µm for supragingival margins. Lofstrom and Barakat reported that the supragingival margins of the crowns considered clinically well-fitting by several dentists were of 7 to 65 µm. After a 5-year study conducted on more than 1000 restorations, McLean and von Fraunhaufer concluded that marginal gap of 120 µm should be the limit of clinical acceptability[15].

Different protocols have been used to evaluate the marginal fit such as direct microscopic examination, which is the most frequently used strategy, cross section view of cemented specimens, silicone replica technique, laser videography, profilometry, x-ray microtomography, etc. In this study, direct viewing under digital microscope Hirox KH-8700/x150 magnification was used. An image analyzing software allowed precise and accurate data collection.

Contrepois et al suggested that a tooth specimen should be prepared in accordance with clinical conditions and the common use of teeth or metallic models with overly simplified shapes and a flat occlusal surface that bear no relation to actual tooth anatomy, should be discontinued. Finish lines that exhibit some degree of curve should be preferred because they better simulate the presence of a gingival margin[15]. In this study, the preparation of the tooth specimen was based on these recommendations.

The aim of this study was to compare marginal fit of lithium-disilicate (LD/IPS e.max CAD) and leucite-reinforced (LR/IPS empress CAD) crowns fabricated with two different chairside CAD/CAM systems: CEREC MCXL and PlanMill 40. Both systems are used to fabricate ceramic restorations with different software and comparable milling systems. However, there is insufficient information in the literature about which of them produces the better marginal fit[15].

The first null hypothesis is that there will be no difference in marginal fit between crowns fabricated with CEREC MCXL and PlanMill 40. The second null hypothesis is that there will be no difference in marginal fit between LD and LR CAD crowns.

Terminology

Traditionally, Dental CAD/CAM CEREC terminology has been to say “milling” for CAM process. However, with introduction by CEREC of carbide burs to their milling systems, it was specified that using carbide burs is “milling” and using a diamond bur is “grinding.” Additionally, the difference between milling and grinding lies in the nature of procedure. Milling consists on carbide burs cutting into the block with punching motion, currently limited to bis-acrylics and zirconia. Grinding is when diamond burs grind off material in planes to make the shape of the restoration[17], like in case of e.max and empress CAD crowns. In this study the authors decided to use “milling” to reflect the status quo in the literature but “grinding” would be more accurate and precise term.

Materials and Methods

An extracted human mandibular molar (#19) was mounted in auto polymerizing methacrylate resin (Diamond D, Keystone Industries, Cherry Hill, NJ, USA) and then prepared in the full clinical set-up using a high-speed electric dental handpiece with water spray (NSK Presto Aqua II High Speed Lab System, Brassler USA, Savannah, GA, USA), high speed suction and diamond burs (8847KR.31.025, 8379.31.018, 6811.31.037FG, 8845KR.31.018 Brassler USA, Savannah, GA, USA) as recommended by manufacturer. Fixed lathe arrangement was used to stabilize handpiece while preparing the taper and digital lever, to align the lathe table in horizontal plan. The tooth specimen was prepared as per Ivoclar Vivadent guidelines for full-coverage posterior crown including: rounded internal line angles with preservation of occlusal anatomy, at least 1 mm axial and occlusal reduction with modified shoulder of at least 1 mm, slightly above the CEJ level. The preparation height was 4 mm with a taper of about 6.9 degrees (Figure 2).

Fig. 2 A

Fig. 2 B

Fig. 2 C

Figure 2:

A: Tooth specimen prepared mimicking clinical conditions. Fixed lathe arrangement used to stabilize handpiece while preparing the taper.
B: Tooth specimen in axial plan showing circumferential shoulder.
C: Tooth specimen in sagittal plan showing TOC and anatomical contours.

The prepared molar was then secured in a typodont (M-860) with adjacent and opposing Ivorine teeth (Figure 3).

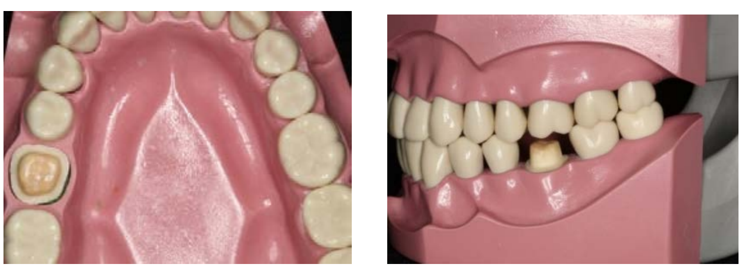

Fig. 3 A

Fig. 3 B

Figure 3:

A: Tooth specimen mounted in a typodent, axial plan.
B: Tooth specimen mounted in a typodent, sagittal plan.

Twelve digital impressions were obtained by corresponding CAD acquisition systems: CEREC Omnicam and Planmeca PlanScan. Each scan was used twice to design and fabricate one LD and one LR full-contoured crown specimens utilizing the factory default settings (Figure 4).

Fig. 4 A

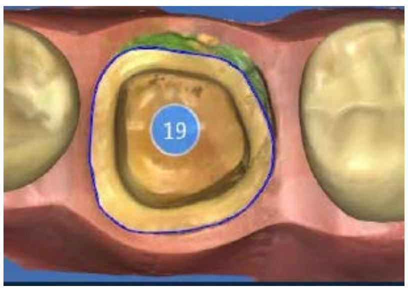

Fig. 4 B

Fig. 4 C

Fig. 4 D

Fig. 4 E

Fig. 4 F

Fig. 4 G

Fig. 4 H

Figure 4:

A: CEREC Omnicam
B: Scanned tooth specimen on CEREC
C: Designed crown on CEREC, buccal view.
D: CEREC MCXL.

E. Planmeca PlanScan
F. Scanned tooth specimen on Planmeca
G. Designed crown on Planmeca, buccal view
H. PlanMill 40

Following fabrication, each crown was placed on tooth specimen and visually verified for any gross misfit. Four crowns were found inacceptable with evidently misfitting margins. They were all fabricated with CEREC MCXL machine: three crowns were LD and one, LR. The crowns were replaced with better fitting new crowns after remilling from previous scans and designs.

All LD crowns were crystalized according to manufacturer’s instructions using a dental laboratory furnace, Programat P700, Ivoclar-Vivadent.

The crown specimens were assigned to four testing groups (n=12):

Group 1: LD/IPS e.max CAD CEREC MCXL,

Group 2: LD/IPS e.max CAD PlanMill 40,

Group 3: LR/IPS empress CAD CEREC MCXL (using the same scans as group 1),

Group 4: LR/IPS empress CAD PlanMill 40 (using the same scans as group 2).

The tooth specimen was then stored under dark conditions at 37 ± 1 °C and 98 ± 1% humidity.

For blinding purposes, each crown randomly received a numeric code (1-24) for identification (two crowns had the same number). Then the occlusal surface of each pair was masked with white or red dental wax and placed in the container with corresponding number (Figure 5).

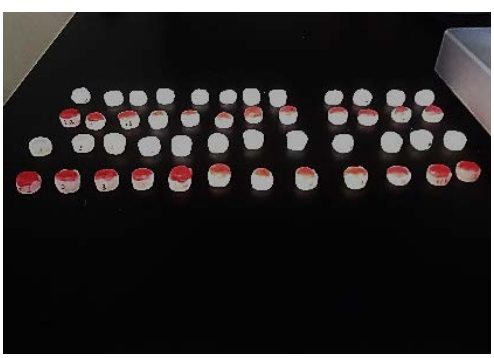

Fig. 5 A

Fig. 5 B

Figure 5:

A. A total of 48 crowns with red or white utility wax covering occlusal surface to blind the evaluator.
B. Numbered plastic containers (1-24) holding two crowns of each color.

To acquire measurements, the tooth specimen was marked at 16 evenly distributed locations around the margin. First, F, M, L and D locations were identified and marked with a green sharpie marker, followed by MF, ML, DL and DF locations. Finally, the spaces between marked locations were further equally divided and identified as MFa, MFb, MLa, MLb, etc. The tooth specimen with successively placed crowns was mounted in horizontal jig and submitted for measurements under digital microscope, Hirox KH-8700 set at 150x optical zoom.

As the crowns were not cemented, they were maintained in a stable position with a plastic bloc mimicking a cotton roll-like pressure when delivering the crown clinically (Figure 6).

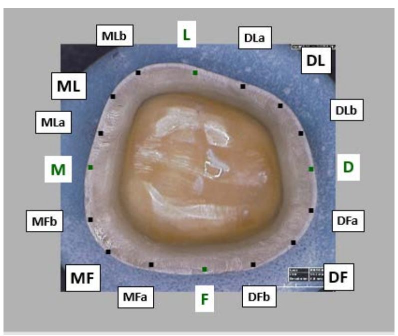

Fig. 6 A


Fig. 6 B

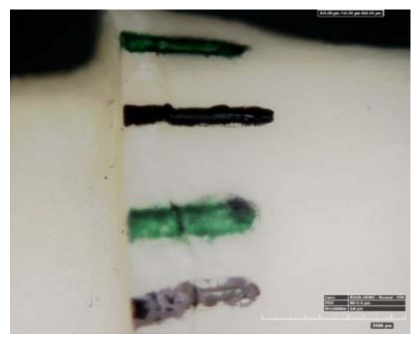
Fig. 6 C

Figure 6:

A: Gingival margin in axial view on tooth specimen showing 16 measurement sites.
B: Tooth specimen with crown in horizontal jig stabilized with plastic block mimicking cotton roll-like pressure.
C: Part of gingival margin with marked measurement sites, horizontal view.

Three measurements were made at each location and an average of these three was the mean marginal fit for that point. In total, 48 measurements were collected with 16 mean measurements for each site. All measurements were accomplished by one calibrated evaluator (Figure 7). Once the measurements for all crowns were made at the specific location, the tooth was rotated counterclockwise to the next site.

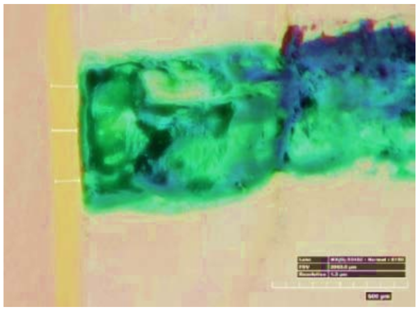
Fig. 7 A

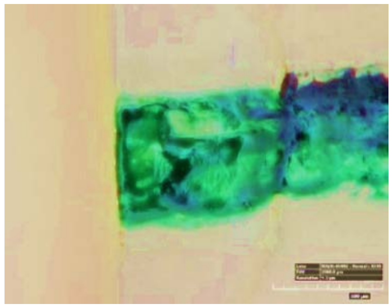
Fig. 7 B

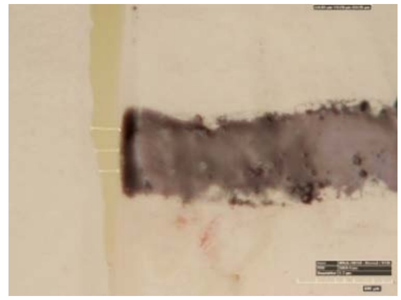
Fig. 7 C

Figure 7:

A: measurement with regular marginal gap
B: measurements in the absence of marginal gap (0µm)
C: measurements witt irregular marginal gap

Results

The independent samples Kruskal-Wallis analysis was used to compare four groups (separate analysis for each material). A 95 percent level of confidence ($p = 0.05$) was used with all analyses. No statistical difference was found when the mean marginal gap was compared (Table 1). The lowest mean marginal gap and the lowest standard deviation (SD) was found in fourth group (LR/IPS empress PlanMill 40) with 35.41 µm and 5.98 µm respectively, followed by the first group (LD/IPS e.max CEREC MCXL) with 37.40 µm and 11.61 µm, third group (LR/IPS empress CEREC MCXL): 41.74/20.67 µm and second group (LD/IPS e.max PlanMill 40): 47.57/14.84 µm. All mean marginal values were below 50 µm and below the limit of clinical acceptability of 120 µm.

	Group	Mean	SD	N
1.	LD/IPS e.max CAD CEREC MCXL	37.40	11.61	12
2.	LD/IPS e.max CAD PlanMill 40	47.57	14.84	12
3.	LR/IPS empress CAD CEREC MCXL	41.74	20.67	12
4.	LR/IPS empress CAD PlanMill 40	35.41	05.98	12

Table 1: Mean marginal gap and standard deviation (SD) for each group (µm). Kruskal-Wallis Test ($p=0.05$) failed to show a statistical difference among the groups.

The box plots at the Figure 8 show the minimum, median and maximum mean values for each group. The minimum mean values of 3 out of 4 groups was below 20 µm and below 30 µm for all 4 groups. The median values, represented by a line between two colors in each box plot were between 20 and 50 µm. Finally, the highest mean values were no greater than 80.34 µm.

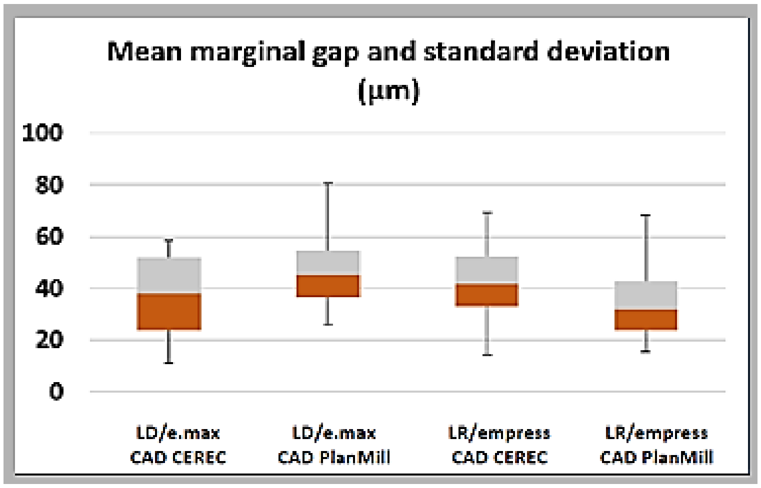

Fig. 8: Box plots of mean marginal gap and standard deviation (µm)

The box plots at Figure 9 show the individual marginal gap discrepancies that varied from zero µm in all groups to 246 µm in second group (LD/IPS e.max Plan Mill 40). Each group in this study had one or more crowns with individual or mean measurements above clinically acceptable limit of 120 µm. A total of 14 crowns had 62 individual measurements above 120 µm and 11 crowns had the mean measurements above clinically acceptable limit at one or several locations. For analysis purposes, these crowns were identified as the outlier crowns but they were all clinically acceptable.

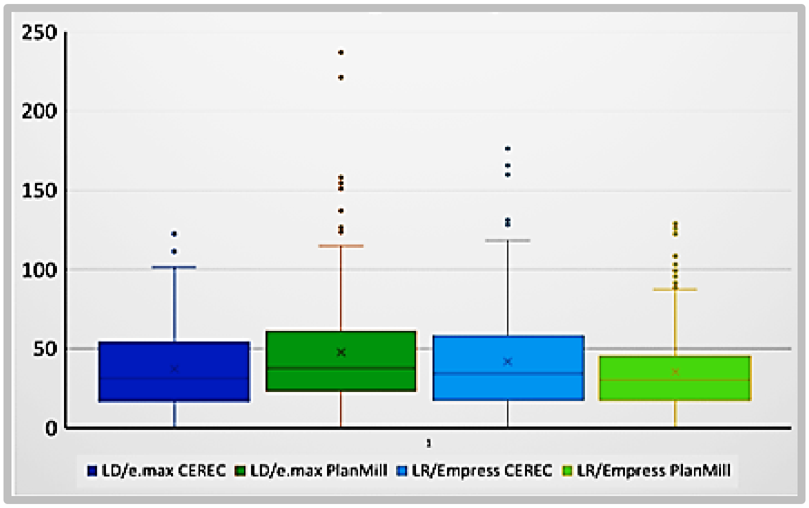

Fig. 9: Box plots of the individual marginal gap discrepancies that varied from zero µm in all groups to 246 µm in LD/IPS e.max PlanMill 40 group

When the mean marginal gaps were compared for each location, five out of sixteen sites demonstrated statistically significant discrepancies: MF, DLa, D, DFa and DF (Table 2 and Figure 10). In addition, there were sites with noticeably smaller measurements for all groups: L and DLa when compared to the sites with the higher measurements: F and MFa. Finally, the highest mean measurement was 80.34 µm at MFa site in the second group (LD/IPS e.max PlanMill 40) and the lowest: 10.93 µm at DLa site in the first group (LD/e.max CEREC MCXL). All discussed differences were not statistically significant.

Group	F	MFa	MF	MFb	M	MLa	ML	MLb
LD/e.max CAD CEREC	44.36	44.74	19.83	23.55	57.3	27.11	26.47	33.74
LD/e.max CAD PlanMill	71.53	80.34	72.81	46.48	44.5	27.89	51.02	26.28
LR/empress CAD CEREC	34.18	46.73	14.37	41.72	62.3	57.03	49.04	69.29
LR/empress CAD PlanMill	46.56	68.13	51.92	41.6	32.9	23.7	56.22	30.92

Group	L	DLa	DL	DLb	D	DFa	DF	DFb
LD/e.max CAD CEREC	22.44	10.93	23.78	58.53	58.52	54.47	50.59	42.16
LD/e.max CAD PlanMill	25.74	34.87	56.79	53.32	48.97	42.22	36.77	41.93
LR/empress CAD CEREC	29.7	15.48	35.06	52.08	52.74	40.23	41.49	26.44
LR/empress CAD PlanMill	25.34	38.22	41.31	30.6	23.77	19.75	15.53	22.57

Table 2: Mean marginal gaps per location (µm) for each group.

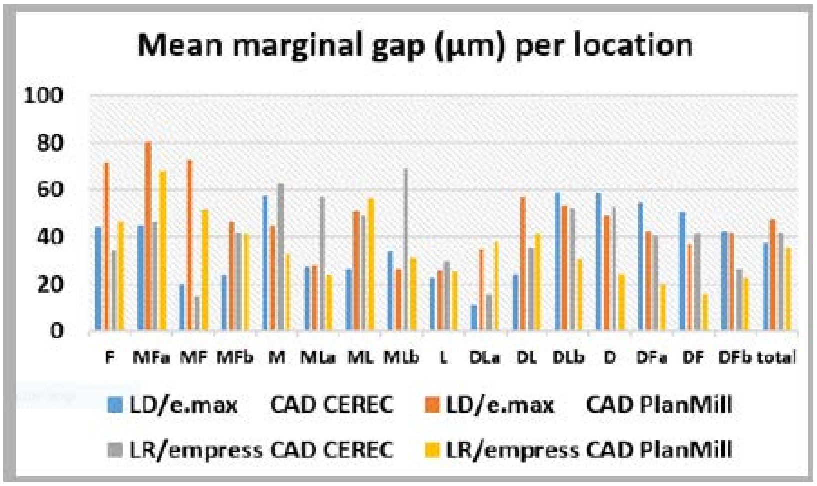

Figure 10: Mean marginal gap per location.

Discussion

This study evaluated the accuracy of the milled margins of two CAD/CAM materials: LD/IPS e.max CAD and LR/IPS empress CAD using two different milling machines: CEREC MCXL and PlanMill 40. The first null hypothesis that there would be no statistically significative difference in marginal fit between two CAD/CAM systems was retained. The second null hypothesis that there would be no statistically significative difference in marginal fit between two CAD/CAM ceramics was also retained.

The mean marginal gaps for all groups in this study were within the range of clinical acceptability of less 120 µm: 47.57 µm for LD/IPS e.max CAD PlanMill 40, 41.74 µm for LR/IPS empress CAD CEREC MCXL, 37.4 µm for LD/IPS e.max CAD CEREC MCXL and 35.41µm for LR/IPS empress CAD PlanMill 40.

Four CEREC crowns were replaced before the beginning of the study due to gross misfit detected visually after initial milling. The remilled crowns from the same scans and designs produced visually acceptable results and were included in the study. The misfit might be due to CEREC milling unit issues encountered during manufacturing phase. Some crowns had to be milled more than once due to interrupted or uncompleted milling cycles with the error messages. The CEREC MCXL milling unit used in this study was in service for about ten years and shared among several dental providers and lab technicians in a large dental clinic so the wear and aging of the machine might justify technical difficulties. Contrary to CEREC MCXL, no technical issues were encountered with PlanMill 40 that was not commonly used in the clinic before.

All groups included in the study had one or more crowns with a mean marginal gap above clinical acceptability of 120 µm at one or more measurement sites and identified as the outlier crowns. They represented 23% of all fabricated crowns (11 out of 48 crowns). 72.7% of them were fabricated with PlanMill 40 (8 crowns) and 27.2%, with CEREC MCXL (three crowns). However, if 4 CEREC crowns rejected at the beginning were included with the outlier crowns, CEREC group would represent 63.6% of outlier crowns (7 crowns). The cause of the marginal discrepancies may be due to the milling unit, the measurement method and instability when aligning the crowns on the tooth specimen. Regardless of the isolated discrepancies, the mean overall gap size for each crown was within a clinically acceptable range of less than 120 µm.

It should be noted that the present study examined the marginal gap in only one dimension, i.e. the distance from the restoration margin to the tooth margin. This most wildly used method[17] is susceptible to two important disadvantages. First, identifying reference points to measure may be difficult and second, it may lead to projection errors. Among alternative methods described by Contrepois et al, x-ray microtomography [13] is the most innovative and accurate method, which delivers 2-dimensionally, or 3-dimensionally imaging and can provide very close sections of the marginal area allowing a great number of measurement sites and easy recognition of the critical distances.

As previously mentioned, the present study examined only one dimension and did not consider the other marginal gap elements such as internal gap, over- or under-extended margins, vertical, horizontal and absolute marginal discrepancy and seating discrepancy as shown on Figure 11.

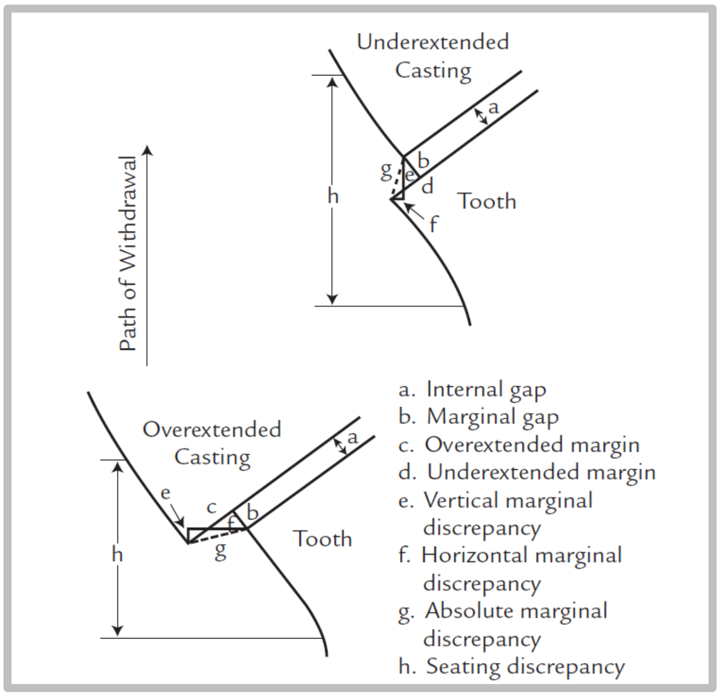

Figure 11: Different measurements that may affect marginal fit

The marginal integrity of LR and LD crowns were similar regardless the system used for fabrication; this study could not identify a noticeable difference in the quality of the margins.

LD/IPS e.max CAD is made of a lithium disilicate glass-ceramic and delivers excellent esthetics and superior strength. It has an average flexural strength of 500 MPa, making it the ideal high-strength solution for single-unit anterior or posterior crowns. LR/IPS empress CAD is made of a leucite reinforced glass-ceramic and is suitable for highly esthetic single-tooth restorations with an average flexural strength of 185 MPa.

This study evaluated 16 sites and 48 measurements. There is no agreement in the literature concerning the number of the measurement sites. Groten suggested taking 50 measurements while Gassino argued that 18 observation points were necessary for in vitro study and 90 measurements for crowns manufactured from intraoral impression. Contrepois et al noted in the systemic review that majority of studies did not fulfill these criteria[15] .

There were several limitations in this study: the sample size, the measurement method, the number of measurement sites, the tooth type and side, the technical condition of the milling unit, the horizontal position of the tooth specimen and instability when aligning the crowns on the tooth specimen. Concerning the tooth type and side: two of nine studies found that tooth type affected marginal fit and one of eight study found that the side varied significantly[14]. In clinical situation, the complexity of preparing and making digital impression of posterior tooth may be more challenging and may justify the differences. In our in vitro study, however, the fact that some lingual sites were slightly smaller than facial remains unknown. The crowns were manually placed on a tooth to the best fitting position and then stabilized with a light horizontal pressure; however, it did not mean that they were correctly positioned three-dimensionally. Also, the measurements were made in the horizontal position and the crowns were not cemented on the tooth as they would be clinically, which might produce different results.

Conclusion

Under the conditions of this study, the following conclusions were drawn:

1. There was no statistical difference in marginal fit between two different ceramic materials included in this study (LD/IPS e.max CAD and LR/IPS empress CAD).
2. The performance of CEREC MCXL milling unit was comparable to the PlanMill 40 for both tested materials.
3. All combinations produced crowns with clinically acceptable marginal fit.
4. Occasional misfit may be due to the milling unit; re-milling the new crown from the existing scan and design may give better fitting crown.

Disclaimer

The authors report no conflicts of interest. The information and views expressed in this article are those of the authors and do not reflect the official policy or position of the US Air Force, the Department of Defense, or the US government.

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