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## Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM

Effrosyni A. Tsitrou \*, Simon E. Northeast, Richard van Noort  
Department of Adult Dental Care, School of Clinical Dentistry, University of Sheffield, Claremont Crescent, Sheffield S10 2TA, UK

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### Abstract

**Objectives:** To examine the marginal fit of resin composite crowns manufactured with the CEREC 3 system employing three different margin designs; bevel, chamfer and shoulder, by means of a replica technique and a luting agent.

**Methods:** Three master casts were fabricated from an impression of a typodont molar tooth and a full-coverage crown prepared with a marginal finish of a bevel, a chamfer and a shoulder. Each cast was replicated 10 times (n = 10). Scanning of the replicas and crown designing was performed using the CEREC Scan<sup>TM</sup> system. The crowns were milled from Paradigm MZ100<sup>TM</sup> composite resin blocks. The marginal fit of the crowns was evaluated with a replica technique (Aquasil<sup>TM</sup> LV, Dentsply), and with a resin composite cement (RelyX<sup>TM</sup> Unicem, Aplicap<sup>TM</sup>) and measured with a travelling microscope. Statistical analysis was performed using two-way ANOVA.

**Results:** For the replica technique the average marginal gaps recorded were: Bevel Group 105±34  $\mu$ m, Chamfer Group 94±27  $\mu$ m and Shoulder Group 91±22  $\mu$ m. For the resin composite cement the average marginal gaps were: Bevel Group 102±28  $\mu$ m, Chamfer Group 91±11  $\mu$ m and Shoulder Group 77±8  $\mu$ m. Two-way ANOVA analysis showed that there was no statistically significant difference between the three groups of finishing lines regardless of the cementation technique used.

**Conclusions:** The marginal gap of resin composite crowns manufactured with the CEREC 3 system is within the range of clinical acceptance, regardless of the finishing line prepared or the cementation technique used.

**Keywords:** Resin composite Resin composite crowns Dental materials CAD/CAM CEREC Marginal gap Replica technique

\*Corresponding author

Tel.: +44 114 271 7924; fax: +44 114 266 5326.

E-mail address: e.tsitrou@shef.ac.uk (E.A. Tsitrou).

## **1. Introduction**

The increasing demand for tooth-coloured restorations in the posterior region has intensified the evolution of new restorative techniques and processing routes. The introduction of computer-aided design/computer-aided manufacture (CAD/CAM) technology in dentistry has allowed the shaping of high-performance materials that could not otherwise be easily shaped to form a dental restoration.<sup>1</sup> The CEREC system is only one of the plethora of CAD/CAM systems available today. It was introduced more than 15 years ago and constitutes the only one that can be used both at the chairside and in the laboratory.<sup>2,3</sup> Several researchers have criticized the marginal fit of these restorations.<sup>3,4</sup> However, improvements in the CEREC apparatus and software have made the fit more acceptable through precise operating procedures.<sup>5</sup> Numerous studies have evaluated the clinical success of computer-assisted fabrication methods and in particular the marginal accuracy of these restorations, showing promising results.<sup>6-13</sup>

Recently a new resin composite block (Paradigm MZ100, 3M ESPE Dental Products) has been introduced for the CEREC system, which according to the manufacturers combines some of the best attributes of ceramics and polymers.<sup>14</sup> For ceramic restorations, a shoulder or broad chamfer preparation is recommended, but for resin composite less invasive chamfer and bevel preparations have been used extensively for direct cavity designs.<sup>15</sup> It was therefore of interest to study whether the application of more conservative finishing lines would influence the marginal fit of CEREC restorations using that material. Thus, the purpose of this study was to compare the marginal fit of resin composite crowns fabricated with the CEREC 3 CAD/CAM system employing three different margin designs: a shoulder, a chamfer and a bevel, by means of a replica technique and a luting agent. The purpose of using two methods of cementing the crowns was to determine any difference between the two cementation techniques.

## **2. Materials and methods**

A lower left first molar typodont tooth (Frasaco A3, 3-6, Frasco Franz Sachs & Co., GmbH) was selected in order to prepare three master casts. The intact typodont tooth was positioned on a wax base, and enclosed in a plastic ring before

taking an impression, using an addition-curing vinyl polysiloxane material (Dublislil-HC, DREVE-DENTAMID-GMBH, Lot No.: 4801 A+B, Germany). Both proportioning and mixing were undertaken in accordance with the instructions given by the manufacturer. On completion of setting the ring and typodont tooth were removed and the impression was cleaned of any debris under running water and air-drying with compressed air.

Three master casts were fabricated from the impression in blue die stone (Blue Die Stone, TechCeram; Lot No.:990401/B) mixed in accordance to the manufacturers' instructions (mixing ratio P:W 100 g/22 ml). To permit a more accurate flow of the die stone, a surface tension reduction agent (Tensilab; Lot. C199E, Zehnmack, Italy), was applied to the surface of the silicon impression. The mixed die stone was carefully vibrated into the impression and left to set under vacuum for 30 min.

Each cast was prepared for a full-coverage crown according to the following protocols: an occlusal reduction of 2 mm and an axial reduction of 1.2 mm were prepared, using an air rotor hand-piece (W&H) followed by a speed increasing micromotor (KaVo BELLA torque 629) for the final details. Each cast had a different marginal design: (1) a 45° bevel, (2) a chamfer and (3) a 90° shoulder (Fig. 1). A parallel diamond bur (Komet CE, ISO 806 314-837) was used for the preparation of the shoulder; a round end taper diamond bur (Komet CE, ISO 806 314-881) was used for the chamfer preparation and a bullet pointed diamond bur (Komet CE, ISO 806 314-886) for the preparation of the bevel. A tungsten carbide bur was used to refine the margins (Ash England, FGSS 556 36/009, Komet CE ISO 500 314-H297 and Komet CE ISO 500 314-H283).

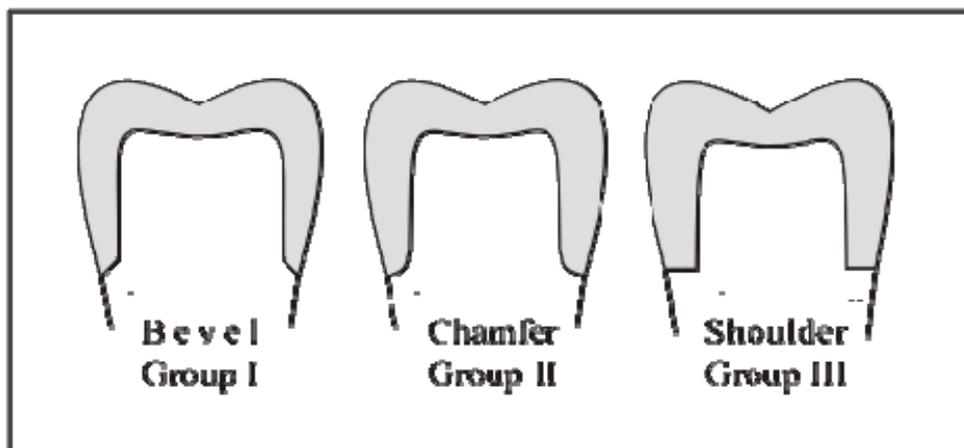
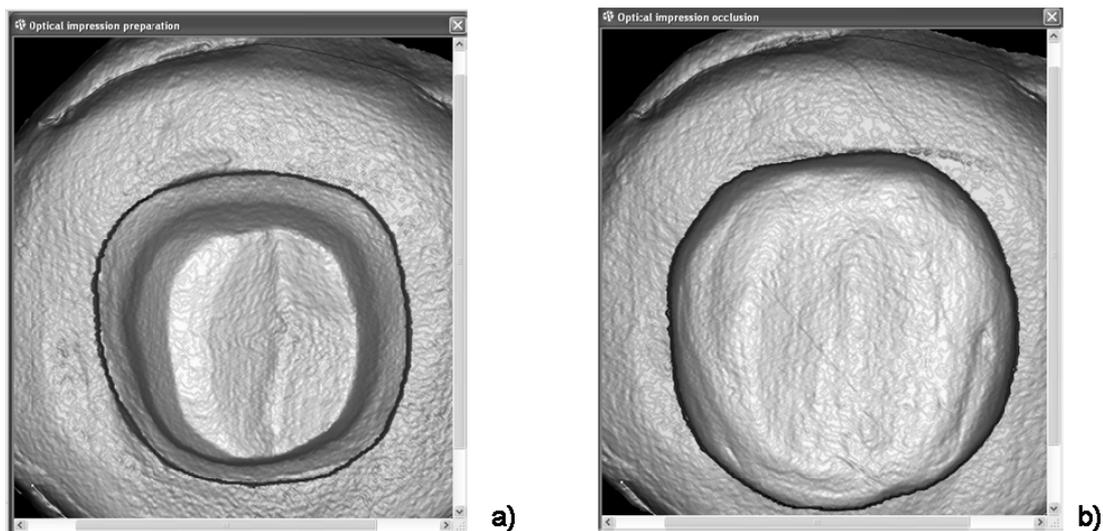


Figure 1 Schematic diagram of each different preparation (not to scale).

An impression was taken of each cast to fabricate a series of 10 replica dies for each marginal design using the materials and techniques previously described. Each replica was fixed to a special model holder provided with the CEREC Scan (Sirona Dental Systems GmbH) and was inserted in the aligning tool before scanning. CEREC powder (VITA Zahnfabrik, D-79713 Bad Sackingen, Germany) was applied evenly before scanning was initiated. The Cerec 3 software (v.1.61 R991) was used for the designing of the restorations. Correlation was selected as the design mode, which belongs to the two-impression methods, in which the three-dimensional data of two optical impressions are combined.<sup>16</sup> The optical recording of the cavity is called “preparation impression” and the optical recording of the occlusal morphology is called “occlusion impression”. The latter could either be the pre-existing occlusal surface of the tooth, or a newly waxed up occlusion. In this case, a crown was waxed-up for the “occlusion impression” (Fig. 2). All scanning and designing procedures were repeated for each replica separately. ParadigmMZ100 blocks for CEREC (size 14, shadeA3) were selected to construct 10 identical crowns for each of the three marginal configuration groups. The scanner and the milling unit were calibrated at the beginning of the study and recalibrated each time the computer software requested it with the use of the calibration specimen and pins provided with the system. A new set of milling burs was used for each group, even though not requested by the software. The luting space was set to 10 mm.



**Figure 2** Screen shots from the Cerec software showing the scanned images of (a) the “preparation impression” and (b) the “occlusion impression”.

## 2.1. Measurement of marginal fit

The marginal gap was evaluated by means of a replica technique and a luting agent. It was determined according to terminology previously reported by Holmes et al.<sup>17</sup> as the vertical distance from the internal surface of the crown to the prepared tooth surface close to the preparation finish line (Fig. 3).

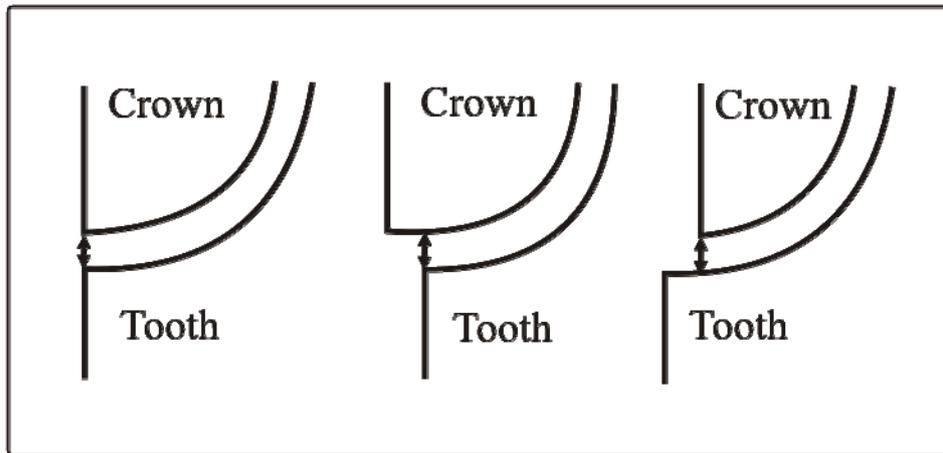


Figure 3 Points of measurement of the marginal gap of different marginal situations.

### 2.1.1. Replica technique

A light-body silicone rubber impression material (Aquasil LV<sup>TM</sup>, green colour, Dentsply-Detrey GmbH D-78467, Germany) was used for the purpose of the cementation. Each crown was filled with the light-bodied material and placed on the corresponding replica with a constant defined load of 40 N for 3 min using a tensometer (Loyds Instrument Model LRX).

After setting of the silicone rubber the crowns were removed from the models. The film of the impression material adhered to the inner surface of the crown in all instances. To support the thin silicone film, a heavy-bodied material with a contrasting colour (Aquasil Putty, blue colour, Dentsply- Detrey GmbH Lot No.: 0407000850, Germany) was placed in the crown to form one piece with the film.

After setting of the supporting heavy-bodied material each silicone replica was removed from the crown and carefully segmented with a sharp surgical blade buccolingually and mesiodistally into four pieces. To provide a consistent series of locations for sectioning and measuring, an index was made with a heavy-bodied material (Aquasil Putty). The marginal gap was measured using a travelling microscope (MITUTOYO<sup>TM</sup>) at 30x magnification.

### *2.1.2. Resin composite cement*

After removal of the silicone film each crown was cleaned and was cemented onto the replicated model with resin composite cement (RelyX™ Unicem Aplicap™; Self-Adhesive Universal Resin Cement, Lot 179205, 3M ESPE AG, Dental Products, D-82229, Germany). The cementation process followed the manufacturer's instructions and the same loading conditions were applied as for the replica technique.

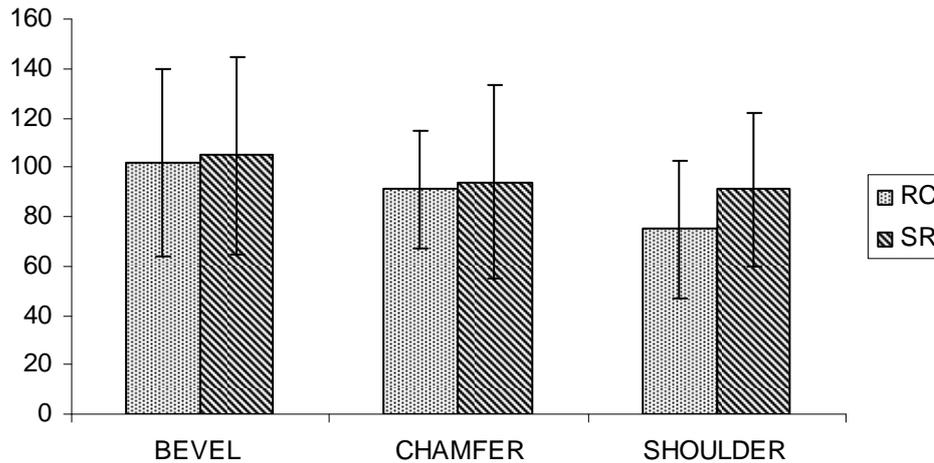
After setting of the cement the models were sectioned buccolingually and mesiodistally with a diamond wheel (LECO VC-50). The silicone index that was made for the sectioning of the silicone replicas was used again to provide matching locations of measurement. Four sections were produced for each model. Each section was embedded in acrylic resin (Buehler Sampl-Kwick Fast Cure Acrylic Kit, No.20-3560) for easier handling. In that way four acrylic embedded specimens were made for each model, which were then polished and examined under the travelling microscope (30 x magnifications) to measure the marginal gap of the crowns.

## **2.2. Statistical analysis**

All data were analyzed with respect to the different preparation design. The average marginal widths and standard deviations (S.D.) were calculated. The statistical package SPSS was used and two-way analysis of variance (ANOVA) was performed to look for significant differences between different finishing lines and different cementation techniques and their interactive effect on the marginal gap.

## **3. Results**

The mean values and standard deviations of the marginal gaps recorded for all groups are listed in Table 1 and shown graphically in Fig. 4. Two-way ANOVA analysis showed that the p-values for the two factors (marginal finish and cement type) were both greater than .05 (marginal finish:  $p = .090$ , cement type:  $p = .364$ ), thus the results were not significantly different at the 5% level (Table 2). Also, as shown in Table 2, the interactive effect of marginal finish and cement type is not significant ( $p = .781$ ), indicating that there is no statistical difference in marginal gap for different finishing lines and cement type combinations.



**Figure 4** Comparison of the average values and standard deviations of the marginal gap of the Cerec crowns measured with the replica technique and with the resin cement in the three groups (mm, WS.D.). RC, resin cement; SR, silicone replica.

**Table I** Average values and Standard Deviations of the Marginal gap of the Cerec crowns of each marginal design. ( $\mu\text{m}$ ,  $\pm\text{SD}$ ),  $n=10$

Groups	Bevel SR	Chamfer SR	Shoulder SR	Bevel RC	Chamfer RC	Shoulder RC
Average	105	94	91	102	91	77
SD	34	27	22	28	11	8

SR silicone replica, RC resin cement

**Table II** Results of Two-way ANOVA analysis

	Type III Sum of Squares	df	Mean Squares	F	Sig.
Marginal Finish	.003	2	.002	2.536	.090
Cement Type	.001	1	.001	.841	.364
Marginal Finish and Cement Type	.000	2	.000	.248	.781

## 4. Discussion

The purpose of this study was to investigate the option of applying more conservative marginal configurations compared to a traditional shoulder finish line with the use of a CAD/CAM system and a resin composite block. The importance of conserving tooth tissue is unquestionable and has been stated by many researchers up till now.<sup>18-20</sup> The principles of minimal invasive dentistry are getting more widely spread among clinicians and more people are willing to apply them in practice.<sup>21, 22</sup>

However, while there may be an impetuous to apply minimal preparation designs, it is not clear what constrains may be imposed on tooth design by the material used and the method of fabrication. If materials and design are inappropriate then this can increase the probability of restoration failure.

The success of a restoration is determined by various factors, among which is the marginal fit of the restoration. Lack of adequate fit is potentially detrimental to both the tooth and the supporting periodontal tissues, due to cement solubility or plaque retention.<sup>17</sup> However, the definitions of marginal fit vary considerably among investigators and often the same term is used to refer to different measurements, or different terms are used to refer to the same measurements.<sup>17</sup> In the present study the marginal gap was determined according to terminology previously reported by Holmes et al.<sup>17,23</sup> Overcontours or undercontours of the crowns margins were not evaluated in this study.

Two common techniques to measure the marginal gap are measurement of embedded and sectioned specimens, and measurement of the replica of the marginal gap. The replica technique, described initially by McLean and von Fraunhofer, has been a reliable and valid non-invasive method to determine the adaptation of crowns to tooth-structure.<sup>24-26</sup> Since then other researchers have used this method to measure crown film thickness.<sup>23,25,26</sup> In this study both methods have been used in order to evaluate the effectiveness of each technique to measure the marginal gap.

The mean marginal gap of CEREC crowns reported in the current study was between 91 and 105  $\mu\text{m}$  when silicone was used as a cement and 75 and 102  $\mu\text{m}$  when a resin composite cement was used. These findings are far from the theoretically based requirements according to which the cementation film thickness should be between 25 and 40  $\mu\text{m}$ .<sup>27</sup> However, most authors agree that marginal openings or inaccuracies of less than 120  $\mu\text{m}$  seem to be in the range of clinical acceptance with regard to longevity.<sup>24,25,28,29</sup>

For different all-ceramic systems the marginal gap reported in several studies was within the range of 1–161  $\mu\text{m}$ .<sup>23,28,30,31</sup> With regard to the values of gap widths of Cerec crowns reported by previous investigators a comparison of the results can be confusing. Variations in type of tooth used, differences in restoration designs, preparation procedures, testing methods and whether the fit was determined before or after luting, are parameters that will influence the results obtained. Moreover, to the authors' knowledge, a limited number of published studies on the marginal fit of

Cerec crowns exist in the literature. In a recent study by Nakamura et al. the marginal gaps of CAD/CAM crowns reported ranged between 95 and 108  $\mu\text{m}$  when the luting space was set to 10  $\mu\text{m}$ , which are close to the results reported in the present study.<sup>32</sup> However, the measuring method adopted differed from that of the current study as the marginal gap was measured without cementing the crowns with the use of a profile projector.

In another study by Bindl et al., the average marginal width reported for anterior Cerec crowns was much lower than the average marginal gaps reported in that study ( $59.9 \pm 7 \mu\text{m}$ ).<sup>33</sup> However, the methodology followed in that study differed in many ways to the methodology followed in the present study. One difference was the fact that the fit of the anterior crowns was checked prior to cementation with a coloured chap-stick and all marked areas were manually removed. In that way, though, the luting space set by the computer was increased manually. Moreover, Nakamura et al. in their study concluded that when the software setting for the luting space was set to 30–50  $\mu\text{m}$  the quality of marginal fit was better than when the luting space was set to 10  $\mu\text{m}$ .<sup>32</sup> The values reported by Nakamura et al. when the luting space was set to 30 or 50  $\mu\text{m}$  was within the range of 53–67  $\mu\text{m}$ , which are not very far from the marginal gap reported by Bindl et al. In the present study no coloured chap-stick or other fit checker was used to remove manually any premature contacts, as there was no sign that the crowns did not fully sit when examined visually. For the same reason that the crowns had an acceptable fit when examined visually, the luting space in the parameter settings in the Cerec 3 software was left at 10  $\mu\text{m}$ . However, it may be worth investigating further if the use of different luting spaces would have produced better readings of the marginal gap.

The results obtained in the current study show that there were no statistically significant differences in the marginal gap between the three groups of finishing line (Bevel, Chamfer, and Shoulder) regardless the cementation technique used. In addition, power law calculations showed that for the sample size used to prove any statistically significant difference, the discrepancy between the groups would have had to be greater than ~50  $\mu\text{m}$  and this was not the case.

Although there was no significant difference between marginal gaps for crowns made with the same finishing line, whether cemented with light bodied silicone material or resin composite cement, the values reported for the resin composite cement were lower than the values obtained with the replica technique.

This could be attributed to the different flow ability of the materials, with the resin composite displaying better flow. However, the results of the study show that for the materials used both methods demonstrate similar results and are both reliable in measuring the marginal gap.

Finally, based on the observation that the marginal widths reported for the bevel and the Chamfer Group were within the clinical acceptable marginal gap limits, it could be concluded that crowns with a marginal finish other than shoulder can be fabricated with the Cerec 3 system, offering the same level of marginal adaptation as other all-ceramic crowns. However, further in vitro and in vivo studies are necessary if a less invasive approach is to be adopted with the use of resin composite blocks.

## **5. Conclusions**

Within the limitations of this study, it can be concluded that the mean marginal gaps of resin composite crowns fabricated with the use of CEREC 3 system were within the range of clinical acceptance regardless the finishing line prepared. Also for the materials used both methods to measure the marginal gaps were found to be sufficient and not statistically significant different. However, in order to accept a less invasive design with the use of that system more studies will be needed to examine other aspects of marginal fit and also the behaviour of other restorative materials.

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