

# Interface Dimensions of CEREC-3 MOD Onlays

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**Abstract** - Evaluation was undertaken of the interface dimensions of MOD ceramic onlays fabricated using the Cerec 3 system. A master die was prepared on a maxillary second premolar Ivorine tooth from which 20 Cerec 3 onlays and 20 feldspathic onlays were made. A total of 80 cement analogues were produced using elastomeric impression material and sectioned orthogonally. Interface dimension was measured using Image Analysis Software. The ceramic onlays constructed using Cerec 3 demonstrated significantly larger cement lute space compared with laboratory produced feldspathic porcelain onlays with mean thickness of  $201.3 \pm 78.0 \mu\text{m}$  and  $139.7 \pm 49.7 \mu\text{m}$  respectively ( $P < 0.001$ ). Large interface dimensions were particularly noted in the proximal boxes. The multiple variables involved in the construction of the Cerec onlays as well as the complexity of the onlay design may be contributing factors to the large cement space.

KEY WORDS: Interface dimension; Internal fit; ceramic restorations; MOD ceramic onlays; CAD-CAM; CEREC 3.

## INTRODUCTION

Computer-aided design/computer-aided manufacturing (CAD/CAM) equipment was introduced to dentistry in the early 1980s<sup>1</sup>. The number of dental CAD/CAM systems commercially available is growing. These systems range in complexity and application, from manual copy milling of inlays to fully computer-controlled systems with a complex library of tooth forms enabling the automated production of crowns and bridges.

In 1984, Cerec 1 was the first generation of CAD/CAM equipment which allowed chairside fabrication of ceramic restorations<sup>2</sup>. However it did not receive wide acceptance due to inherent limitations. In particular it had a single cutting tool and tooth preparation was adapted to fit the resultant limited morphology. Provision of the manufactured inlays was also reported to be challenging due to large marginal gaps<sup>3</sup>. The Cerec 2 unit was introduced in 1994 and claimed improved shape-grinding techniques, and improved resolution with the ability to fabricate all-ceramic posterior crowns<sup>4</sup>. The Cerec 2 technique was however limited by an inefficient computer<sup>5</sup>. The construction and the control software of the latest Cerec 3 unit was written for the Windows platform (Microsoft) and runs on a personal computer integrated into the recording unit. In turn, this permits accelerated automatic processes and a sufficiently user-friendly program<sup>6</sup>.

Traditionally, marginal fit and interface dimension are important criteria used in the clinical evaluation of fixed restorations. Denissen *et al*<sup>7</sup> evaluated the marginal fit for Cerec onlay restorations on stone dies and demonstrated residual marginal gaps of  $85 \mu\text{m}$ . Although there is no general consensus of opinion as to what constitutes a biologically acceptably marginal gap, it is agreed that the cement dissolution and cement wear may in turn compromise the

longevity of the restored tooth<sup>8,9,10</sup>. Internally, the width of the interface gap between the internal fitting surfaces and the supporting tooth as well as the physical properties of the lute and adhesive union with the substrates may have a determining effect on the ability of the restored tooth to withstand the physical-chemical degradation process of the oral cavity<sup>11</sup>. The ideal lute may be considered to fill a uniform space between the fitting surface of the restoration and the tooth preparation. Should this not be achieved, binding of a restoration on the fit surface of the tooth may be problematic if small areas are loaded as ceramic restorations are more fragile than their cast metal counterparts<sup>12</sup>. Leinfelder *et al*<sup>13</sup> suggested the luting space for resin cement should not exceed  $100 \mu\text{m}$ . Molin *et al*<sup>14</sup> examined four-point bending strength of a ceramic-cement-ceramic sandwich with 20-, 50-, 100-, and 200- $\mu\text{m}$  cement thicknesses to determine optimum mechanical conditions and concluded that an interfacial gap of 50 to  $100 \mu\text{m}$  was ideal for composite cement. The interfacial gap may also have a significant bearing on the degree of polymerisation of photo-activated composite resin in this area and hence the overall rigidity of the restored tooth as excessive resin cement thickness has been demonstrated to reduce the fracture strength of the restoration under load<sup>15</sup>. Conversely, an extremely thin layer of bonded cement could also jeopardize the restoration as polymerization shrinkage may produce high internal stresses<sup>16</sup>. It has been suggested that where internal gaps are large, fine-hybrid composite luting materials with a modulus of elasticity close to that of dentine should be used to provide higher fracture resistance of the bonded restorations<sup>17</sup>; although finite element analysis showed that the influences of elastic modulus and cement thickness of composite luting agent were minimal in resisting deflection with applied force in all-ceramic crowns<sup>18</sup>.

The mean internal cement space of Cerec 2 crowns has been investigated, ranging from  $122 \pm 45 \mu\text{m}$ <sup>19</sup> for posterior crowns to  $141 \pm 21 \mu\text{m}$  for anterior crowns<sup>20</sup>. The difference has been attributed to the user-configured dimensional setting for the cement space which was set at  $0 \mu\text{m}$  and  $30 \mu\text{m}$  respectively<sup>19</sup>. However, examination on the effect

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of computer's luting space setting on the marginal and internal fit of Cerec 3 crowns demonstrated the marginal fit was better at a cement lute setting of 30  $\mu\text{m}$  than 10  $\mu\text{m}$  and the internal fit was independent of the cement space setting at 10 and 30  $\mu\text{m}$ <sup>21</sup>.

Cast gold onlays have long been recognized as successful restorations<sup>22,23</sup>. The onlay design restores the entire occlusal surface with partial coverage of axial surfaces. It is conservative of tooth structure and may play a role in protecting teeth from fracture<sup>23</sup>. Today, aesthetics demands are such that ceramic onlays are considered more acceptable than gold onlays<sup>24</sup>. Recent clinical survival study showed that Cerec 3 ceramic partial crowns was comparable to gold partial crowns for up to 2 years, despite higher incidence of ceramic chipping associated with ceramic partial crowns which did not warrant replacement<sup>25</sup>. The marginal fit of the inlay type Cerec 3 restorations have been extensively described in many laboratory and clinical studies<sup>26, 27</sup>. Evaluation of internal fit of all ceramic molar CAD/CAM crowns showed that Cerec inLab<sup>®</sup> had internal cement lute space of 114 + 58  $\mu\text{m}$  and was not significantly different from other CAD/CAM crowns<sup>28</sup>. To date, there was little information relating to the interface dimensions of onlay restorations of more complex design fabricated using the Cerec 3 unit. This study aimed to compare the interface dimensions of CAD/CAM Cerec 3 ceramic onlays with feldspathic onlays produced on refractory dies.

## MATERIAL AND METHODS

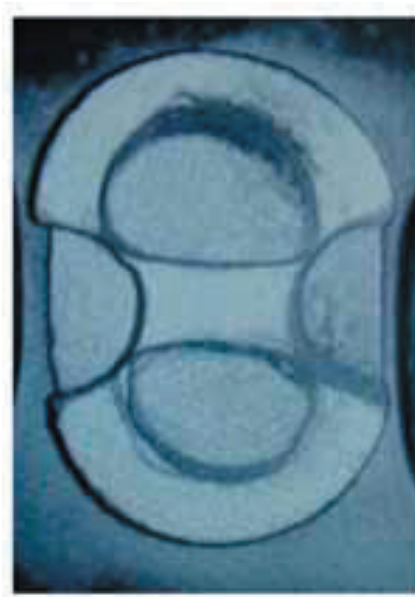
An Ivorine<sup>A</sup> maxillary second premolar was prepared to receive a MOD ceramic onlay and was used as the master die. The preparation was performed following the Cerec preparation guidelines using diamond-coating burs (L767.9C and LSP767.9VF)<sup>B</sup> in an air turbine with spray cooling. The master die was prepared with (1) an occlusal reduction of 1.5 mm and functional cusp bevel, (2) 1 mm wide rounded shoulder finish lines both buccally and palatally (3) an occlusal isthmus with width of 2 mm and depth of 1.5 mm from the occlusal surface, (4) mesial and distal boxes with 2 mm axial wall height and 1.5 mm floor width mesiodistally (Figure 1).

### Onlay fabrications

For every Cerec onlay construction, a thin layer of titanium oxide powder<sup>C</sup> was sprayed onto the master die prior to making the optical impression. A Cerec intraoral scanner<sup>C</sup> was used to make 20 optical impressions and from these 20 Cerec onlays were produced (Figure 2). The preparation was outlined with the electronic cursor. Once the outline of the floor was completed, the Cerec 3 unit<sup>C</sup> automatically detected the cavosurface margin and provided a proposal for a cavosurface margin line. The extrapolation design mode was chosen to generate individualized occlusal morphology. The Cerec unit would then suggest the correct size of Vita Blocks Mark II<sup>D</sup> required to mill the onlay. One parallel sided cylindrical diamond bur of 1.6mm diameter<sup>C</sup> and one 45 degree tapered cylindrical bur<sup>C</sup> of the same diameter were used to mill the onlay. The milling burs were calibrated prior to milling and replaced when advised by the program. The adhesive gap was set at 25  $\mu\text{m}$  to ensure the marginal fit was not compromised<sup>21</sup>.



**Figure 1.** MOD ceramic onlay preparation on an Ivorine maxillary second premolar.



**Figure 2.** Image of tooth preparation taken by Cerec optical scan.

Once the onlays were constructed, a diamond bur in an air turbine was used to remove the grinding stub, smooth any irregular external margins and any small positive areas to facilitate the seating of the restoration.

Twenty impressions of the master die were made using light and heavy body additional cured polyvinyl siloxane (President)<sup>E</sup> in sectioned plastic stock trays. Twenty refractory dies<sup>D</sup> were constructed and 20 feldspathic porcelain onlays were made using Vitadur Alpha porcelain<sup>D</sup>. Porcelain was built up in layers using a brush and condensed with a spatula to reduce firing shrinkage. A well compacted onlay was then fired according to the program in the Vitadur Alpha chart<sup>D</sup>.

### Measurement of interface dimension

The method used to measure the discrepancy between the fit surface of the ceramic onlay and the preparation was based on the elastomeric cement analogue technique first described by McLean and Von Fraunhofer<sup>29</sup> and later modified by Shearer *et al*<sup>30</sup>. The modified method allowed for the use of a single master die and multiple sections of onlay/cement/die analogues. A blue low-viscosity addition-cured polyvinyl siloxane (Extrude)<sup>F</sup> impression material was used as the cement analogue. The onlays were cemented onto the master die and held with finger pressure for 5 minutes before the onlay was carefully removed, leaving the cement analogue on the master die. Another low-viscosity addition-cured polyvinyl siloxane (Panasil Contact Plus)<sup>G</sup> impression material of contrasting purple colour was then placed on top of the cement analogue to simulate the onlay. The combined onlay/cement analogues were then carefully removed from the underlying master die when set. The same impression materials were then applied to the intaglio surface to simulate the die. The resultant elastomeric blocks then represented the onlay/cement/die assembly. Two elastomeric blocks were constructed for each onlay giving a total of 80 blocks.

A jig was used to ensure all impression blocks were sectioned parallel and at identical points. One impression block of each onlay was cut in a buccolingual orientation at three parallel points to produce one section through the mid-point of isthmus (BL-I), one section across the mid-point of the mesial box (BL-M) and one section across the mid-point of the distal box (BL-D). The second impression block was sectioned in a mesiodistal orientation through the mid-point (MD).

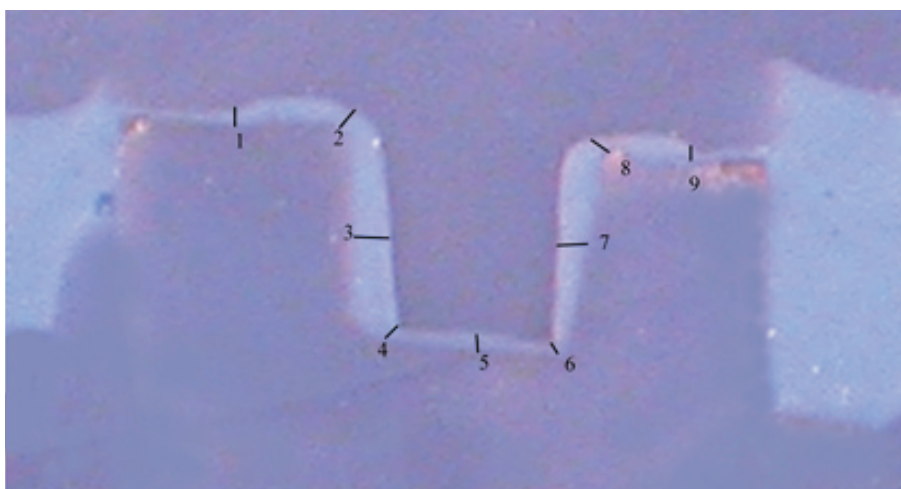
Image analysis software<sup>H</sup> was used to measure the cement thickness (nominal accuracy 1  $\mu\text{m}$ ). The image of each sectioned cement analogue was captured on a video camera<sup>I</sup>. The camera output was connected to a personal computer containing the image analysis software. The

colour contrast between the cement analogue and the die/onlay analogues allowed for easy identification of the interfaces. Nine paired points were measured on each BL-D, BL-M and MD section and 17 paired points were measured on the BL-I section. A total of 44 paired points were measured for each ceramic onlay (Figures 3-6). All points on the die analogue were identified by measuring from fixed references on the preparation surfaces to ensure repeatability. A tangent was drawn by the program at each of the points from which measurements were made at 90 degrees to the fitting surface of the onlay analogue.

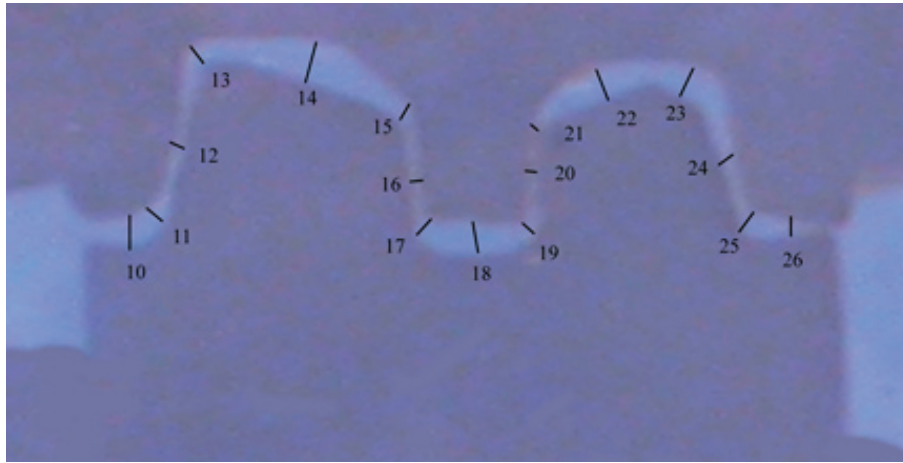
All onlay construction, sectioning and measurement were performed by one operator. To assess the measurement consistency of the operator, one ceramic onlay was randomly selected and all 44 paired points were measured 10 times on separate occasions to prevent eye fatigue or memory bias. The measurements showed standard errors ranging from 1.7  $\mu\text{m}$  to 2.9  $\mu\text{m}$ . This was considered acceptable for the purpose of the study.

### Statistical analysis

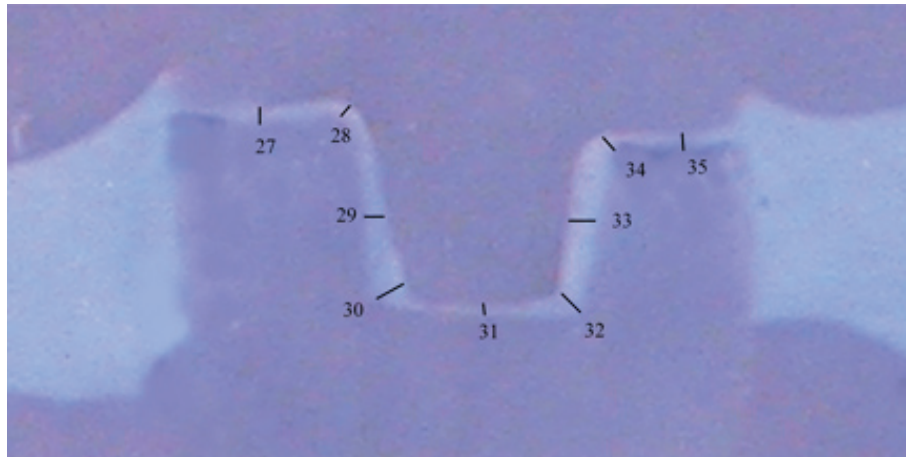
Group means and standard deviations were calculated for cement analogue thickness for both Cerec and feldspathic groups. A two-way hierarchical analysis of variance (ANOVA) was performed, with the factors being *point measured* and *ceramic groups* with samples hierarchical within groups. Statistical significance accepted at the 5% level. Assumptions of normality and constant variance were verified using residuals. A post hoc analysis (Bonferroni) following a one way ANOVA for each ceramic group was used to evaluate which points measured were significantly different within each ceramic groups. Furthermore, two-sample *t*-tests were used to compare points in the two ceramic groups, using a significance level of 0.01 to adjust for multiple testing.



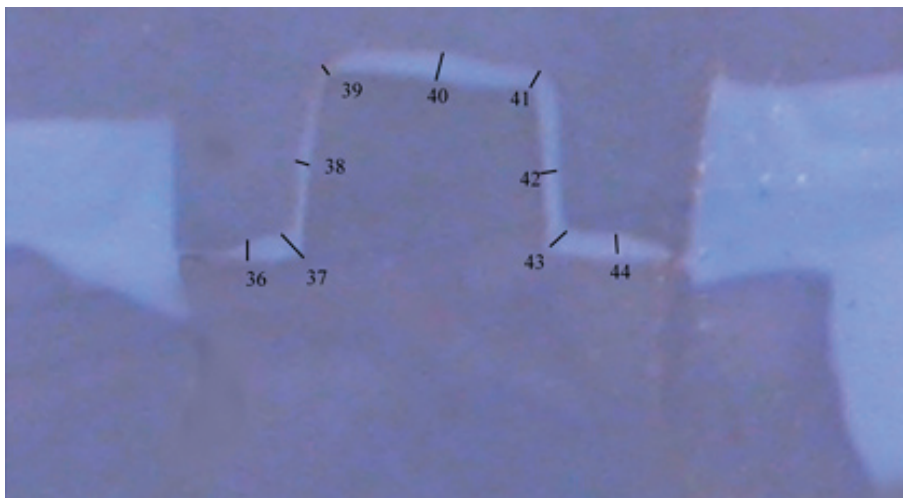
**Figure 3.** Measurement sites of paired points 1 to 9 on the buccal-lingual section through mid-point of distal box.



**Figure 4.** Measurement sites of paired points 10 to 26 on the buccal-lingual section through mid-point of isthmus.



**Figure 5.** Measured paired points 27 to 35 on the buccal-lingual section through mid point of mesial box.



**Figure 6.** Measurement sites of paired points 36 to 44 on the mid mesio-distal section.

**Table 1.** Two-way hierarchical ANOVA of data

Source	Sum of Squares	df	Mean Square	F	P-value
Groups	1669387.133	1	1669387.133	217.634	<0.001
Point	2469486.008	43	57429.907	23.534	<0.001
Sample(Group)	291483.281	38	7670.613	3.143	<0.001
Group*Point	763111.438	43	17746.778	7.272	<0.001

**Table 2.** Summary of post hoc analysis for Cerec group

Sections measured	Mean of mean cement thickness ( $\mu\text{m}$ )	Mean of mean standard deviation ( $\mu\text{m}$ )
BL-M and BL-D	248	63
BL-I and MD	169	37
BL-D	257	59
BL-M	238	67

**Table 3.** Summary of 2-sample t-tests

Points measured	Mean of mean cement thickness ( $\mu\text{m}$ )	Mean of mean standard deviation ( $\mu\text{m}$ )
10,15,16,24,26,36,37,38,39,42,43 (Feldspathic group)	139	46
10,15,16,24,26,36,37,38,39,42,43 (Cerec group)	149	33
All other points (Feldspathic group)	140	35
All other points (Cerec group)	213	54

## RESULTS

The 2-way hierarchical ANOVA showed significant differences between the ceramic systems ( $P < 0.001$ ), among the various points studied ( $P < 0.001$ ) and among the various onlay samples ( $P < 0.001$ ) (Table 1). The Cerec group possessed significantly larger mean cement analogue thickness compared to the control group. The mean cement thickness of Cerec onlay was  $201 \mu\text{m}$  with the 95% confidence interval ranging from  $181$  to  $215 \mu\text{m}$ ; and the mean cement thickness of feldspathic onlays was  $140 \mu\text{m}$  with the 95% confidence interval ranging from  $131$  to  $149 \mu\text{m}$ . There was a significant interaction between the systems and the points measured ( $P < 0.001$ ), so that the differences between points were investigated separately for each system and vice versa.

The post hoc analysis showed that within the Cerec group, the mean cement thicknesses measured on BL-M and BL-D sections were significantly larger than those measured on BL-I and MD sections ( $P < 0.05$ ). The mean cement thickness measured in BL-M was not significantly different from that measured in BL-D ( $P > 0.05$ ) (Table 2).

The two-sample *t*-tests showed that there were no significant differences in the cement analogue thickness at paired points 10,15,16,24,26,36,37,38,39,42,43 measured between the Cerec and feldspathic onlay groups (Table 3). These points clustered around the BL-I and MD sections.

All other points showed significant differences between the two groups.

## DISCUSSION

Examination on the marginal fit of Cerec 3 crowns employing 3 different margin designs (bevel, chamfer and shoulder) showed that marginal fit was independent of the finishing line prepared<sup>31</sup>. The master die was prepared with shoulder finishing line in accordance to Cerec guideline to ensure adequate bulk of ceramics. Martin and Jedynakiewicz<sup>11</sup> reported that the internal cement lute thickness of Cerec 2 MOD inlays ranged from  $108 \pm 42 \mu\text{m}$  to  $211 \pm 38 \mu\text{m}$  depending on the site of measurement. Evaluation of internal fit of all ceramic molar CAD/CAM Cerec inLab<sup>®</sup> crowns demonstrated internal cement lute space of  $114 + 58$ <sup>28</sup>. In the present study, the overall mean cement space of Cerec 3 onlays was  $201 \pm 78 \mu\text{m}$ , ranging from  $104 \mu\text{m} \pm 27 \mu\text{m}$  to  $308 \mu\text{m} \pm 63 \mu\text{m}$  according to measurement locations. The larger cement space may be due to the complex preparation design of the MOD onlay chosen for this study. Larger than ideal cement space was also observed in the control group of feldspathic onlays. The multiple internal line angles of the design and the shrinkage of porcelain on firing onto the refractory dies resulted in considerable internal adjustment to allow for the passive seating of onlays onto the master die. The mean

internal cement space of the control onlays was  $139.7 \mu\text{m} \pm 49.7\mu\text{m}$ , ranging from  $76 \mu\text{m} \pm 17 \mu\text{m}$  to  $208 \mu\text{m} \pm 6 \mu\text{m}$ . The internal adaptation of laboratory produced sintered porcelain onlays has been reported to range between 91 and  $308 \mu\text{m}$  and is dependent on the study design and the site of measurement<sup>32,33</sup>.

The mean cement analogue width of the Cerec onlays in the present study ranged approximately from  $100\mu\text{m}$  to  $300 \mu\text{m}$ , with cement widths larger than  $200 \mu\text{m}$  located mainly in the distal and mesial proximal boxes. During milling of the onlay, the machining process automatically incorporates a slightly "wedge-shaped" design for the proximal boxes of inlays/onlays despite the parallel proximal walls prepared. The spacing created allows for the compensation of irregular walls and facilitates seating. This may explain the larger cement space measured in the present study. Furthermore, the widest gaps were located on the distal box. Despite the introduction of dual triangulation as part of the Cerec 3 systems, it has been suggested that a distal shadow exists and this may influence the internal fit of the Cerec restorations<sup>17</sup>. This could explain the larger cement space in the distal box, however the post hoc analysis showed no significant difference for each pair of points measured in the distal box and its mesial box counterparts, except for point 6 measured on BL-D which was significantly larger than its mesial counterpart ( $P=0001$ ). In the present study, measurement of cement analogues along the isthmus (MD section) ranged approximately from  $150 \mu\text{m}$  to  $230 \mu\text{m}$ , and concurred with those published by other investigators<sup>11</sup>. Large cement analogue thickness ( $> 200 \mu\text{m}$ ) was also measured in the BL-I section on the cusps. The occlusal reduction was carried out evenly along the cuspal slopes with a functional cusp bevel on the palatal cusp. The sloping cusps may be a contributing factor to the larger cement space. The Cerec unit reads flat surfaces more precisely but a flatter design would involve more extensive tooth reduction.

When individual measured points were compared between the Cerec and feldspathic onlays, all points measured on BL-M and BL-D were significantly larger than the feldspathic counterparts ( $P \leq 0.01$ ). Use of a high viscosity composite resin has been recommended to increase the wear resistance at the exposed margin of Cerec restorations. The high fracture strength of the machine-made ceramics may allow for the higher cementation forces that would be required without ceramic fracture<sup>11</sup>.

Several factors influenced the overall fit of a Cerec restoration. Potential errors in techniques may occur during the coating of the cavity preparation with reflective powders, intraoral image acquisition of the three dimensional geometry of the cavity preparation; computer program compensation for errors, and milling errors from milling tools<sup>3</sup>. The optical impressions, powder application, and plotting of the restoration outlines are directly controlled by the operator, however these factors may vary each time the unit is used<sup>4</sup>. This variation has been reflected in the ANOVA which showed that there were significant differences between each Cerec specimen. The multiple variables involved in the construction of the Cerec onlays as well as the complexity of the onlay design in this study may be contributory to the large cement analogue thickness reported.

## CONCLUSION

Within the limitations of the study, the interface dimensions of Cerec onlays were found to be inferior to that of the feldspathic onlays, especially in the proximal boxes. This uneven and relatively large cement space may influence the behaviour of the luting cement and may compromise the longevity of the ceramic onlay. Further studies are indicated to assess the effect of various preparation designs on the interface dimensions.

## MANUFACTURER'S DETAILS

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- B. Two Striper, Abrasive Technology Inc., USA
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- D. VITA Zahnfabrik H. Rauter GmbH & Co KG, Bad Säckingen, Germany
- E. President, Coltene AG, Altstätten, Switzerland
- F. Kerr Mfg Co., Romulus, MI, USA
- G. Roydent Dental Products, Rochester Hills, MI, USA
- H. Image Pro Plus, version 4.5 for Windows, Media Cybernetics, Buckinghamshire, UK
- I. JVC TK-870-E color video camera, Victor Company, Japan

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