

# Marginal Gap Evaluation of Metal Onlays and Resin Nanoceramic Computer-Aided Design and Computer-Aided Manufacturing Blocks Onlays

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## Abstract

**Objective** This study was carried out to assess and compare the marginal gap of conventionally used metal onlays and new resin nanoceramic (RNC) (Lava Ultimate block) onlays.

**Materials and Methods** This is an in vitro study using two extracted sound human mandibular molars. One tooth was prepared to receive the metal onlays and another one for the RNC onlays which were fabricated using the computer-aided design and computer-aided manufacturing (CAD/CAM) technology. Twelve metals and 12 ceramic onlays were fabricated before they were placed at their respective preparation and examined under the Leica stereomicroscope, M125C (Leica Microsystems, Wetzlar, Germany) for a marginal analysis. The gap width was measured at 10 predefined landmarks which included 3 points on the buccal and lingual surfaces each and 2 points each on the mesial and distal surfaces, respectively.

**Statistical Analysis** Mann–Whitney post hoc test was used for statistical analysis ( $P \leq 0.05$ ).

**Results** Overall, the RNC onlays showed significant lower marginal gap with the exception of the landmarks 5 and 6 (on distolingual) and no significant difference at landmark 7 (on midlingual). It was observed that the marginal gap were all within the clinically acceptable limit of 120  $\mu\text{m}$ .

**Conclusions** Based on the results obtained, it can be concluded that the RNC CAD/CAM onlays are a promising alternative to the metal onlays.

## Keywords

- ▶ ceramics
- ▶ computer-aided design
- ▶ microleakage
- ▶ minimally invasive dentistry
- ▶ prosthetic dentistry/prosthodontics
- ▶ restorative materials

## Introduction

The marginal fit is one of the most fundamental aspects to consider in the fabrication of a fixed prosthesis. The dimensional accuracy of a fixed prosthesis is considered mandatory for the good clinical performance and longevity of the prosthesis. Thus, it is used as a key criteria for the clinical evaluation of a successful fixed restoration.<sup>1</sup> However, the criteria for judging the accurate internal fit of a restoration have never been as well-defined as the physical and

mechanical properties of the materials.<sup>2</sup> A study by Abduo et al<sup>3</sup> stated that there was no clear guidance and assistance as to establish a clinically acceptable marginal and internal fit. In addition, no standard guidelines are available to measure the gap in vitro or in vivo and because of this, data comparisons between previous studies is also difficult.<sup>2,4</sup>

Explorer and elastomeric disclosing techniques were commonly used for evaluation in a clinical setting, but both techniques did not provide the satisfactory accuracy needed for the detection of a marginal gap.<sup>5,6</sup> McLean and

von Fraunhofer<sup>5</sup> examined the dimensional accuracy of >1000 crowns and concluded that 120  $\mu\text{m}$  was the maximum tolerable marginal opening. However, marginal discrepancy ranging between 100 and 150  $\mu\text{m}$  were also considered clinically acceptable by other authors.<sup>7,8</sup> There is no clear evidence that a certain method of fabrication provides a consistently superior marginal fit. The objective of this study, was to assess and compare the marginal gap of conventional metal onlays (Metaplus VK Dental, GC Europe, Belgium) and new resin nanoceramic (RNC) (Lava Ultimate block, 3M ESPE, United States) onlays.

Metal onlays have been used successfully for many years but during the past decade there has been an increase in the demand for more aesthetic restoration and as a result, most of the studies in recent years have evaluated the marginal gap of ceramic restorations with little information available on metal onlay. An onlay is defined as an intracoronal restoration that fits within the anatomic contours of the clinical crown of a tooth with an occlusal veneer for restoring moderately large lesion on premolars and molars with intact facial and lingual surfaces.<sup>9</sup> An onlay is chosen as a treatment option in such situations, because it involves a more conservative approach following the concept of minimally invasive dentistry.

There is limited dental literature to evaluate the marginal gap of metal onlays even though they have been used a lot clinically. All-ceramic restorations have become very popular over the past few decades due to their ability to mimic the optical characteristics of enamel and dentin.<sup>10</sup> A new material called RNC, by 3M ESP, was introduced into the market recently.<sup>11</sup> It is a direct result of true nanotechnology coupled with resin technology to achieve strength and aesthetic beyond what current feldspathic ceramic and composite blocks can offer. It has good aesthetic due to its high polish retention. It also has a good fracture resistance, and is not brittle. The manufacturer claims that this new material performs equally or better than the glass ceramics and composites due to its unique formulation and processing technique. Nanoclusters provide high strength and wear resistance while nanoparticles give significantly improved polish retention and optical properties.<sup>11</sup>

More importantly, the clinical success of a fixed restoration such as an onlay can be influenced by a marginal gap. The marginal gap is one of the important factors that determine the success of restoration in both metal and ceramic based onlay as ill-fitting restoration may cause damage to the tooth and its periodontium. Poor marginal fit can cause hypersensitivity and secondary caries, and induce the onset of periodontal disease which can lead to failure of the fixed restoration.<sup>12,13</sup> Therefore, the aim of this study was to compare the marginal gap of ceramic and metal restorations. The results of this in vitro study will provide evidence to help clinicians in selecting the better of the two materials regarding patient satisfaction and the best treatment outcome.

## Materials and Methods

Two extracted mandibular molars without caries were cleaned and prepared for the onlay fabrication with one tooth

prepared for the Mesio-occluso-distal (MOD) metal onlay and another one for the RNC onlay. The cavity preparation was done manually, and the preparation design of the cavity was based on the standard onlay preparation recommended by Seymour.<sup>14</sup> For RNC onlay, the cavity outline follows the similar guidelines of cavity preparation for the MOD metal onlay except that all the cavo surfaces margins were well defined and had a 90° butt-joint configuration without the bevel. Furthermore, all the internal line and point angles were rounded to reduce the stress concentration as recommended by the manufacturer.

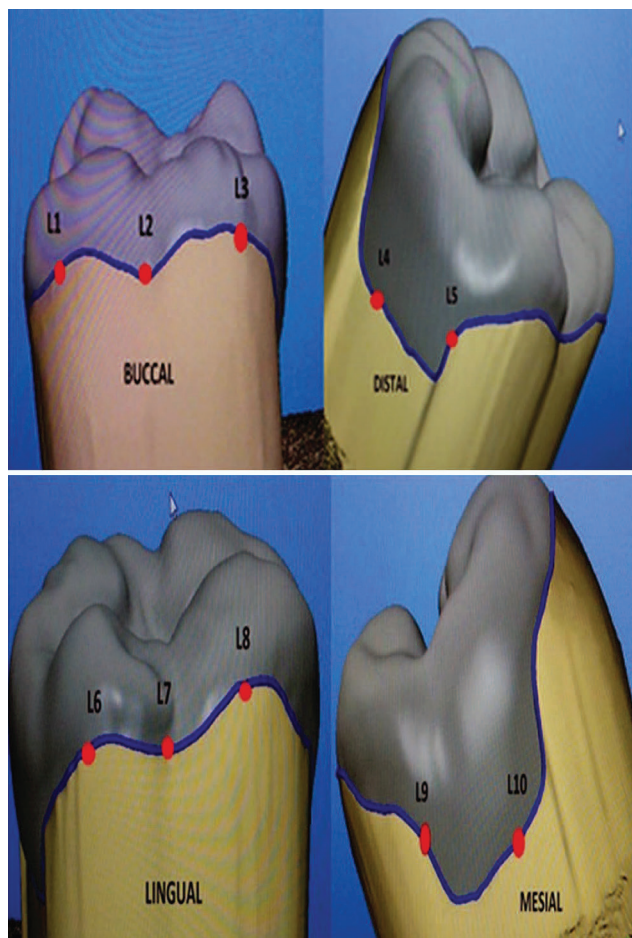
For fabrication of the metal onlays, an impression of the tooth was taken using the light body and heavy body addition silicone (Examix impression material, GC Corp., Belgium). A sectional tray was filled with the impression material and placed on the prepared tooth with adequate finger pressure till the resistance of the stopper was felt. A total of 12 impressions were taken and the models were fabricated.<sup>15</sup>

The fabrication of the RNC onlay was done with the CEREC inLab MC X5 System (Dentsply Sirona Global, New York) using the unit's internal laser scanner to digitize the tooth. The data were then transmitted to a software program (inLab CAM software, Dentsply Sirona Global, New York) using which the onlays were designed. Twelve virtual designs were prepared before milling, one for each of the 12 RNC onlays. A marginal analysis was performed by measuring the marginal gap of the onlays without cementation. This method consisted of image analysis software (Leica Software, Leica Microsystems, Wetzlar, Germany) in combination with a stereomicroscope (M121C, Leica Microsystems, Wetzlar, Germany) with a magnification factor of  $\times 41$ . For all the measurements, the specimens were placed on a metal device to secure the cores at the same position on the dies to ensure that the maximal distance between the outer restoration margin and the cavosurface angle of the preparation was perpendicular to the optical axis of the microscope. The marginal gap of all the onlays margin to the prepared tooth were measured at 10 predetermined landmarks as shown in **Fig. 1a** and **b** (modified from Costa et al)<sup>15</sup> which involved three points on buccal and lingual surfaces each and two points each on the mesial and distal surfaces. No cement or other medium was used to affix the onlays onto the die.

The samples were observed and photographed at  $\times 41$  using a digital camera mounted onto the stereomicroscope and calibrated using a focal point calibration slide. The images were measured using the Leica software (M125C Leica Microsystems, Wetzlar, Germany), and the readings were taken at 7, 14, and 21 days, and the mean was calculated. The Statistical Package for Social Sciences (SPSS-version 20.0., IBM © New York SPSS Statistics) was used to analyze the results obtained in this study. The results of the measurements were analyzed for the median, interquartile range (IQR) and any significant difference ( $p \leq 0.05$ ) was calculated using the Mann-Whitney test.

## Results

The data analysis was divided into two parts. First, the median and the IQR were obtained for both the groups and



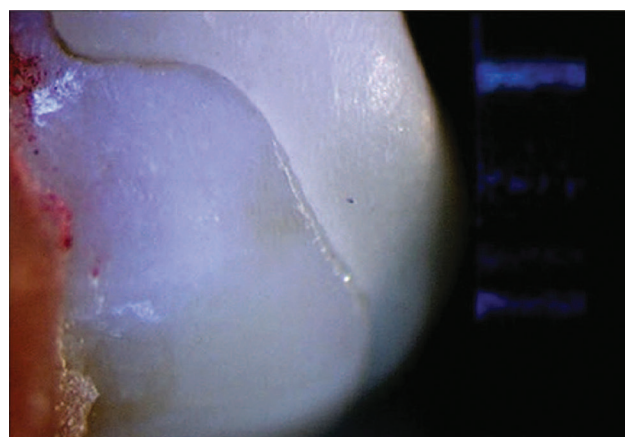
**Fig. 1** (a) Landmark for marginal gap measurement (landmark 1–5). (b) Landmark for marginal gap measurement (landmark 6–10).

then, these were statistically analyzed using the Mann-Whitney test. The results are summarized in **Table 1**. For resin RNC, significant lower marginal gaps were recorded with the exception of the landmark 5 and 6. Measurements recorded for landmark 5 and 6 show that the marginal gap of

the metal group is significantly lower than the corresponding measurements of the RNC group. Landmarks 7 show no significant difference between both onlay groups. Some of the crown margins showed defects such as marginal chipping (**Fig. 2**). These defects occurred in the RNC onlays and appeared to be more prevalent at landmarks 5, 6, and 7.

## Discussion

The marginal fit is an important factor for the success of any restoration. Onlays with a poor fit (marginal gap) are prone to fail as a result of microleakage, cement dissolution, and dental caries. In this study, the fit of onlays was assessed based on the marginal gap measurement. Both materials show marginal gaps  $<120\ \mu\text{m}$  which is within the clinically acceptable limit.<sup>5</sup> In general, there was no definite evidence of the best methodology to assess the appropriate precision of crowns and fixed dental prosthesis.<sup>16</sup> The technique of the laboratory onlay fabrication has been used for years which provide good long-term results in both longevity and survival.<sup>5,17–19</sup> The longevity of each restoration varies and



**Fig. 2** Exemplary under microscope images at  $\times 41$  magnification to demonstrate the characteristic of chipping.

**Table 1** Comparison of median marginal gaps between metal onlay and resin nanoceramic onlay

Marginal gap	Median (IQR)		Z statistic <sup>a</sup>	P
	Metal onlay	Resin nano ceramic		
Landmark 1	62.22 (15.42)	31.13 (13.21)	-3.91	< 0.001
Landmark 2	64.90 (17.78)	61.29 (6.44)	-2.03	0.042
Landmark 3	61.91 (6.54)	42.92 (15.10)	-4.17	< 0.001
Landmark 4	53.02 (16.38)	35.69 (17.57)	-2.95	0.003
Landmark 5	56.60 (18.18)	93.79 (17.97)	-3.97	< 0.001
Landmark 6	66.27 (16.38)	85.39 (3.95)	-3.82	< 0.001
Landmark 7	62.96 (13.93)	64.78 (15.42)	-0.34	0.729
Landmark 8	64.25 (19.25)	50.15 (12.42)	-2.23	0.026
Landmark 9	63.04 (10.76)	27.81 (12.62)	-4.11	< 0.001
Landmark 10	58.81 (15.29)	29.97 (13.34)	-4.16	< 0.001

Abbreviation: IQR, interquartile range

<sup>a</sup>Mann-Whitney test. Lava Ultimate block.

p-value < 0.05 was considered statistically significant.

is affected by many criteria including patient-related, dentist-related, and material-related factors where the handling of dental restorative material under ideal circumstances can produce a restoration that can last for many years.<sup>20</sup>

The fabrication of the metal onlay involves multiple steps which include clinical and laboratory procedures. Errors and mistakes can occur during these procedures; for example, during clinical impression taking, during transportation of the impression to the laboratory or during postimpression prosthesis fabrication. In this study, the challenges were found in controlling and standardizing each step involved in the fabrication of the metal onlays. Each impression was cautiously taken following the specifications of the materials and material handling for the fabrication of the onlay. To minimize flaws, the fabrication of the onlay in the laboratory was done by a competent and experienced technician. However, it is still impossible to control all the variables in combination with human errors which may result in poor marginal fit.

Therefore, the application of new computer-aided design and computer-aided manufacturing (CAD/CAM) technologies along with the new material, RNC can decrease the chances for postimpression inaccuracies as well as laboratory procedure errors. Thus, this will produce better fitting onlay at enhanced cost efficiency. The use of the RNC onlays (Lava Ultimate block), CAD/CAM materials, offer additional advantages over metal onlay fabrication which include saving precious laboratory time, reduced patient visits and shortened chair-side time. This treatment modality may be beneficial for hectic and busy patients who demand instant results on the same day of their dental visit. It also may increase the productivity greatly and may lead to some changes in the production process of dental restorations.<sup>20,21</sup> The advent of CAD/CAM technology facilitates an effective system regarding patient management wherein a dentist can prepare the tooth, design, and fabricate the restoration at the chair-side in a single appointment eliminating the need for impressions and provisional restorations.

Although there was variation at the different sites within the groups, as a whole, RNC group showed consistently a statistically significantly lower marginal gap measurement compared to the metal group. The results of this in vitro study determined that both the materials demonstrated acceptable, marginal gap which is < 120  $\mu\text{m}$ . The results were in agreement with previous studies by McLean and Fraunhofer<sup>5</sup> and Rastogi and Kamble<sup>6</sup> which suggested that 120  $\mu\text{m}$  was maximum tolerable marginal opening. However, an older study by Christensen<sup>22</sup> stated that clinically acceptable margin gap range is from 2 to 51  $\mu\text{m}$ . Overall, RNC showed significant lower marginal gap measured with the exception of the landmarks 5 and 6 which is an area of marginal ridge line angle. This is comparable with a study done previously by Reich et al,<sup>23</sup> which also shows the highest single mean value at landmark where occlusal and internal surfaces are at an acute angle.

The RNC onlays showed marginal chipping which is consistent with a previous study that compared the marginal fit of conventional laboratory heat-pressed (IPS Empress) and chairside CAD/CAM restoration (Cerec 3D). They found that

chairside CAD/CAM restorations exhibited the characteristic of chipping edge fractures whereas, the traditional cast metal onlay restorations showed less prominent edge deficiencies. This might be because, the marginal edges of the CAD/CAM restorations are subjected to stresses during the manufacturing processes.<sup>23</sup> This can be explained by the difficulty to scan and mill at an angle which causes small chipping in those particular areas.

## Conclusions

Within the conditions and limitations of this study, it was concluded that the observed marginal gap of the metal onlays and RNC onlays (Lava Ultimate block) were all within the clinically acceptable limit (120  $\mu\text{m}$ ). Based on the results obtained, the RNC (Lava Ultimate block CAD/CAM) can be considered as an alternative material of choice for onlay restorations instead of cast metal regarding the marginal gap. In conclusion, onlays constructed by RNC (Lava Ultimate block) are comparable or better than those created by traditional cast metal technology with respect to the marginal gap.

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### Conflicts of Interest

None.

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