

## The Effect of Preparation Quality on Marginal Fitness of CAD/CAM Restorations

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### ABSTRACT

Marginal fit of the crown is a key assessment of the fixed partial denture quality. Numerous studies have been performed to evaluate the marginal fit of CAD/CAM all-ceramic crowns fabricated under ideal conditions, but very few studies have investigated the impact of real clinical factors, such as the quality of the abutment preparation. The purpose of this study is to evaluate the effect of preparation quality on the marginal fit of CAD/CAM crowns. Fifteen dental clinicians made three preparations of the upper left first molar on the typodont, and the quality of the preparation was objectively determined using preparation analyzer software. CAD/CAM crowns were fabricated using the standard digital workflow on the CEREC System. The marginal fit of the crown was measured using the Triple-Scan Protocol, and digitally analyzed and measured in 3D with computer software. Out of 45 prepared abutments, 19 were rated “poor” (PP) and 26 were rated “good” (GP). The average marginal gap in PP and GP were 82.13 ( $\pm 9.41$ )  $\mu\text{m}$  and 62.12 ( $\pm 10.11$ )  $\mu\text{m}$ , respectively. Statistical analysis with two-tailed t-test showed p-value  $< 0.01$ , indicating significant difference between the two groups. Within the limitations of this study, the quality of the margin preparation has significant effect on the marginal fitness of the CAD/CAM all-ceramic crown

**Keywords:** Preparation quality, CAD/CAM, Triple scan protocol, Over-mill, Marginal fitness

**Abbreviations:** GP: Good Preparation; PP: Poor Preparation; ME: Marginal Edge; MR: Marginal Ramp; TSP: Triple Scan Protocol

### INTRODUCTION

Recent developments in dental CAD/CAM have vastly improved its technical maturity, producing restorations that are not only clinically acceptable and reliable, but cost-effective as well [1]. An abundance of literature exists that compare the quality and accuracy of restorations fabricated from conventional workflow versus those from digital procedures. In general, their conclusions can be split into two groups. Either the studies concluded that there was no significant difference in quality [2-4], or that digital workflows are more accurate [5-7].

Fitness of a restoration is a measure of accuracy, and it can be evaluated by measuring the space between the restoration and the underlying abutment. McLean et al conducted a 5-year clinical study evaluating marginal fit of crowns, and determined that marginal gaps up to 120  $\mu\text{m}$  were acceptable [8]. Several authors also considered marginal gaps between 100 and 150  $\mu\text{m}$  to be clinically acceptable [9-11]. The source of this large variance in accuracy is of considerable clinical interest, considering that the resolution of most dental milling machines is around 25  $\mu\text{m}$ .

In an in-vitro study, the authors compared the marginal gaps of lithium disilicate crowns fabricated by using three different impressions techniques: one conventional and two digital. The typodont tooth was prepared extra-orally with a clear guide, and the marginal gaps of the final crowns were measured using a stereomicroscope. The overall marginal gaps for conventional and two digital methods were 112.3  $\mu\text{m}$ , 89.8  $\mu\text{m}$ , and 89.6  $\mu\text{m}$ , respectively [3]. In another study extracted molars were prepared extra-orally to the recommended reduction guidelines, and the marginal fitness of their respective CAD/CAM crowns were compared. The study also concluded that marginal discrepancies in all cases

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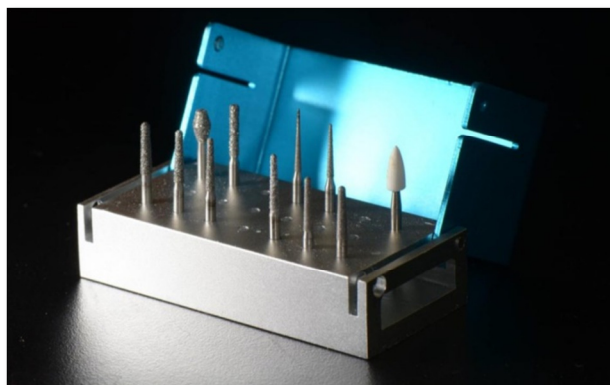
met the clinically-acceptable standard [12,13]. Similar conclusions can be observed from other similar studies that compared marginal fitness of CAD/CAM crowns [14,15].

Most of these studies use ideal abutments either prepared extra-orally or replicated using metal casts. In real clinical situations, ideal preparations are impractical due to a multitude of environmental, human, and technical factors. One study that attempted to investigate the human factor examined the marginal fit of crowns fabricated with the E4Dsystem (PLANMECA, Finland) and its correlation to the quality of the abutment preparation [16]. The prepared abutments were categorized into “excellent”, “fair”, or “poor” quality based on visual inspection. In its discussion, the authors admitted to the possibility of bias and subjectivity with this method. Therefore, the purpose of this study is to use an objective assessment of preparation quality, and to investigate whether the preparation quality has a significant effect on the fitness of the final CAD/CAM crown.

## METHOD

### Preparation

Fifteen dentists from a teaching hospital, with clinical experiences ranging from 2 to 18 years, were recruited as subjects of this study. All participants were given a mandatory 10-minute presentation that reviewed important preparation parameters. Each participant prepared the same tooth (#26) on the typodont (Kao Dental GmbH, Germany) three times. The first preparation was preceded by a 5-minute calibration period, during which the subjects were able to familiarize themselves with the hardware. All subjects were provided with identical sets of new burs (**Figure 1**). In the period between each preparation, the prepared abutment tooth was removed from the phantom-head and the typodont. The subjects were not allowed to see the removed teeth until all three preparations were finished. Once the preparation phase has completed for the subject, the three abutment teeth were collected, rinsed with tap water, labeled, and stored in separate containers.



**Figure 1.** High-speed burs provided to each subject.

### Crown Fabrication

The CEREC Omnicam (Dentsply-Sirona, Germany) was used to create the digital impression of the prepared abutments. Once the scan data has been acquired, it was analyzed using the Preparation Analyzer tool to assess the margin quality of the preparation, which was subsequently categorized into two groups. If the Preparation Analysis showed no warning, then the preparation is assigned into the “good preparation” (GP) group. If the software showed one or more warnings on the margin, then the preparation is designated as “poor preparation” (PG).

For digital restoration design, the original morphology of the unprepared tooth was used as an index. The material selected for fabrication is the feldspathic porcelain Mark II 14-mm bloc (VITA, Germany), and all restoration parameters were set to manufacturer’s recommended defaults. The restorations were milled in the In Lab MCXL (Dentsply-Sirona, Germany) using extra-fine settings with 12Sburs. The burs were replaced after having milled 10 crowns. Each crown was visually inspected for milling defects and re-milled in the off-chance that defects were detected. Then the sprues were removed and polished via a low-speed hand-piece, and the lumen surfaces steam-cleaned before trying-in on the abutment.

### Analysis

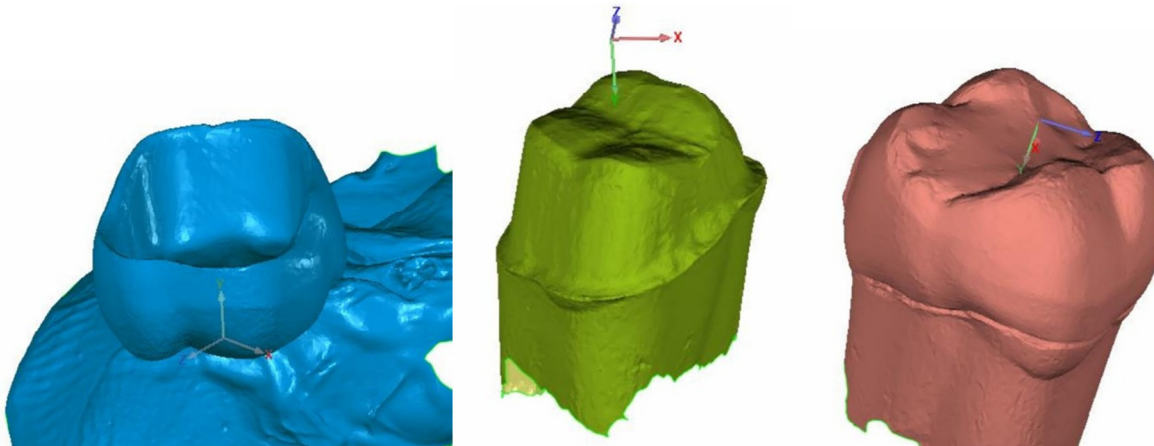
The primary technique used for the data acquisition in 3D marginal fit analysis is the Triple Scan Protocol (TSP) [17]. In this study, the TRIOS intra-oral scanner (3Shape, Denmark) was used as the scanner in the protocol. The Triple-Scan Protocol consists of three scans. First, the crown is fixed in place with beading wax, with the lumen surface facing up and all external axial surfaces exposed (Scan #1). The TRIOS was then used to scan using high-resolution mode. The number of 3D image stacks was limited to under 300, irrespective of the scanning time. After scanning was completed and inspected in the software for holes, the file was converted and saved into ASCII STL file format. For the second scan of the protocol, the prepared abutment scanned in a similar method to the previous step, and the final model was converted into STL file format (Scan#2). Finally, the third scan of TSP consists of both the crown and the abutment in their seated positions (Figure 1). Before the scan, the porcelain crowns were seated onto the abutments with light-body silicone (3M). Maximum finger pressure was applied for 5 minutes until setting, and entire specimen was scanned using the same method as the previous steps (Scan #3).

### 3D Marginal Analysis

Geomagic Studio was used for to create 3D registration of the crown (Scan #1) and the abutment scan data (Scan #2), using the scan data (Scan #3) as reference. The margin of the prepared abutment was divided into two regions. The area from the edge of the margin to the highest curvature before

the axial wall was designated as the marginal ramp (MR) (**Figure 2**). The outer band of MR consisting of all mesh triangles in contact with the edge boundary was designated as the marginal edge (ME). Once these two regions were specified on the abutment, their average distance to the

lumen side of the corresponding crown model can be determined using standard software functions. For each region, the mean and maximum distances across all sampling points were calculated.

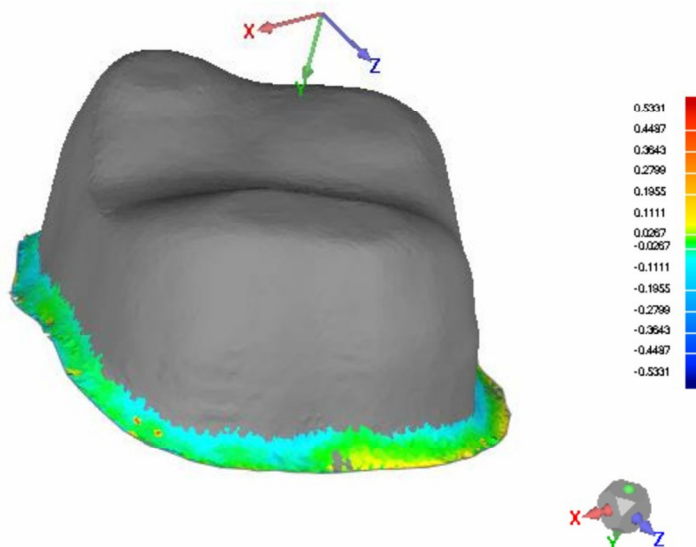


**Figure 2.** Digital impressions of the restoration's lumen and external axial surfaces (left), the prepared abutment (middle), and the restoration bonded to the abutment (right).

## RESULTS

The numbers of samples in PP and PG groups were 19 and 26, respectively. The mean gap measurements using data acquired from TSP were as followed; For ME, the mean gap size for PP was  $82.13 \mu\text{m} (\pm 9.41)$ , while the mean gap size

for GP was  $62.12 \mu\text{m} (\pm 10.11)$ . For MR, the mean gap size for PP was  $99.15 \mu\text{m} (\pm 13.46)$ , while the mean gap size for GP was  $86.25 \mu\text{m} (\pm 14.23)$  (**Figure 3**). No samples were rejected during inspection.



**Figure 3.** Visualization of the marginal gap distances in three dimensions. The colored band indicate the region defined as the marginal ramp.

## STATISTICAL ANALYSIS

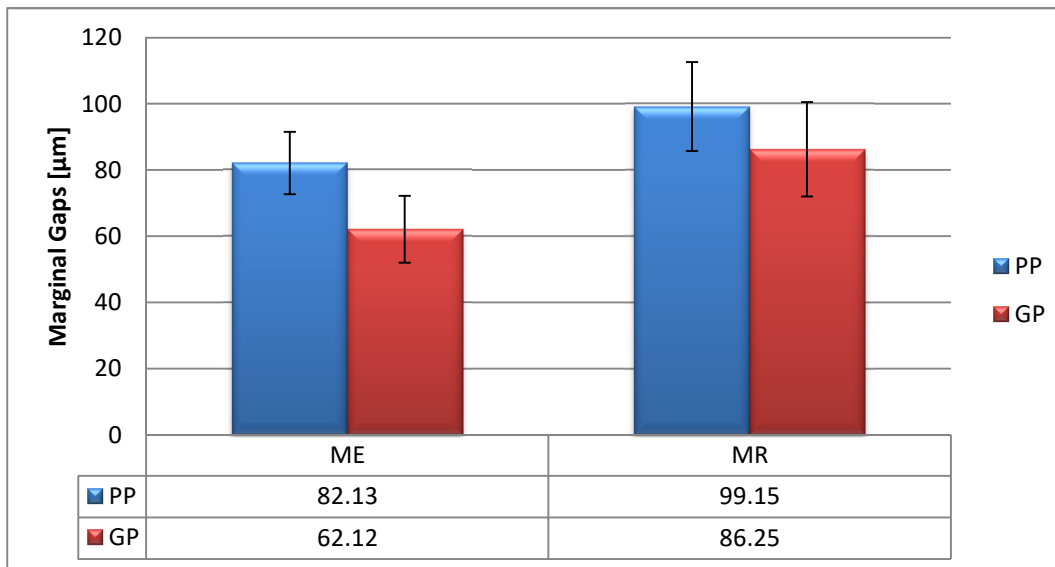
The results for data from ME and MR indicated statistical significance ( $p < 0.01$ ) between PP and GP values. For ME results, the t-score was 6.82 with 43 degrees of freedom. For MR results, the t-score was 2.87 with 43 degrees of freedom.

## DISCUSSION

For CAD/CAM restorations, marginal fitness is often of primary concern because it directly correlates to the long-term health of the dentition and the surrounding tissue [13,18,19]. Marginal fitness, or discrepancy, is defined as

the “vertical dimension from the finish line of the preparation to the margin of the restoration” [20]. Poor marginal adaptation of the restoration can increase micro leakage and plaque accumulation, leading to cement dissolution, secondary caries, and periodontal disease [21]. There is, however, no clear guideline for clinically

acceptable marginal fit. Christensen [22] considered 39  $\mu\text{m}$  to be the acceptable marginal discrepancy according to the linear regression prediction formula. Several authors also considered marginal discrepancies between 100 and 150  $\mu\text{m}$  to be clinically acceptable [8-11].



**Figure 4.** Mean marginal gaps at two different measuring sites. ME: marginal edge; MR: marginal ramp.

While digital workflows have shown to produce clinically acceptable margins [3,12,13], these kinds of studies mostly utilize abutments that were optimally prepared in-vitro. Ucar et al. [23] used machined steel dies to evaluate the internal fitness of laser-sintered crowns. Seker et al. [1] and Baig et al. [15] prepared extracted premolars with a uniform 1 mm rounded shoulder margin to evaluate marginal fit of CAD/CAM restorations. These studies failed to capture the inevitable variance caused by human error. In a real clinical setting, factors such as poor viewing angles, inadequate lighting, mouth opening limitations, and the skills of the dentist can potentially cause teeth preparations to become suboptimal. Therefore, the results from these previous studies represent the best-case scenarios that are very unlikely to occur.

Since in practice, dentists are able to detect gaps at only the margins with a dental probe [22], the criteria for preparation quality in this study is limited to the marginal area. In this study, the average gaps at ME for the PP and PG groups were 82.13  $\mu\text{m}$  and 62.12  $\mu\text{m}$ , respectively. The ME marks the band of area directly adjacent to the edge of the finish line, and the gap values in this study were all within the clinically acceptable value of 120  $\mu\text{m}$  [8]. Furthermore, they are also in agreement with other similar studies that used intra-oral scanners to fabricate single crown restorations [13,15,24-26]. According to a systemic review [27], which performed a meta-analysis on the evaluation of marginal fit of single-unit full coverage ceramic restorations, the mean value of the marginal fit for in-vitro restorations fabricated

after digital impressions was 63.3  $\mu\text{m}$  (95% CI: 50.5–76.0  $\mu\text{m}$ ). Considering that these studies used optimally prepared abutments under controlled settings, the marginal fitness obtained for the GP group in this study (62.12  $\mu\text{m}$ ) is very close to the value obtained in the systemic review. This seems to suggest that if the marginal preparation is of sufficiently quality, then near-optimal marginal fitness can be achieved. On the other hand, if there are areas of roughness or acute angles that can be detected by the analysis software, then these imperfections are transferred to the fitness of the final crown.

The software used for preparation quality assessment, Preparation Analysis, is a simplified version of prep Check (Dentsply-Sirona). It checks the curvature process of the preparation margin, and if the margin exceeds a determined section length of a predefined curvature, the region is highlighted as a warning. The predefined curvature can be indentations or protrusions, and it is correlated to the milling process. The marginal fit of the CAD/CAM crown is dependent on how accurately the milling device can reproduce the contours of the preparation. Since milling is performed with burs, the radius of the bur poses a physical limitation on how fine a detail can be milled. Therefore, small features or contours smaller (i.e. rough surfaces, sharp angles) cannot be perfectly reproduced. When this problem is encountered during the milling pathway analysis, there are two options for the software algorithm. First, to ensure complete seating of the crown, the software will generate a milling path that guarantees milling of all surface features.





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