



# An In Vivo Evaluation of the Fit of Zirconium-Oxide Based, Ceramic Single Crowns with Vertical and Horizontal Finish Line Preparations

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## Keywords

Zirconia single crowns; precision; marginal gaps; horizontal finish line; vertical finish line.

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## Abstract

**Purpose:** Different types of tooth preparations influence the marginal precision of zirconium-oxide based ceramic single crowns. In this in vivo study, the marginal fits of zirconium-oxide based ceramic single crowns with vertical and horizontal finish lines were compared.

**Materials and Methods:** Forty-six teeth were chosen in eight patients indicated for extraction for implant placement. CAD/CAM technology was used for the production of 46 zirconium-oxide-based ceramic single crowns: 23 teeth were prepared with vertical finishing lines, 23 with horizontal finishing lines. One operator accomplished all clinical procedures. The zirconia crowns were cemented with glass ionomer cement. The teeth were extracted 1 month later. Marginal gaps along vertical planes were measured for each crown, using a total of four landmarks for each tooth by means of a microscope at 50 $\times$  magnification. On conclusion of microscopic assessment, ESEM evaluation was completed on all specimens. The comparison of the gap between the two types of preparation was performed with a nonparametric test (two-sample Wilcoxon rank-sum test) with a level of significance fixed at  $p < 0.05$ . All data were analyzed with STATA12.

**Results:** In the group with horizontal finish line preparations, the median value of the gap was 35.45  $\mu\text{m}$  (Iqr, 0.33); for the vertical finish line group, the median value of the gap was 35.44  $\mu\text{m}$  (Iqr, 0.40). The difference between the two groups was not statistically significant (two-sample Wilcoxon rank-sum test,  $p = 0.0872$ ).

**Conclusions:** Within the limitations of this study, the gaps of the zirconium-oxide-based ceramic CAD/CAM crowns with vertical and horizontal finish line preparations were not different.

Metal-free fixed prosthodontic solutions have become increasingly popular.<sup>1-6</sup> They offer improved esthetics with biological and mechanical results similar to those of metal ceramic crowns.<sup>7-10</sup> Zirconia crowns are an option for metal-free solutions. Zirconia's use has been facilitated by the advent of computer-aided design/computer-aided manufacturing (CAD/CAM) systems.<sup>11-15</sup> The use of CAD/CAM systems seems to guarantee the fabrication of crowns with margins as precise as those of metal ceramic crowns described by previous studies.<sup>16-18</sup> Marginal and internal precision of fit is believed to be one of the most important criteria for the clinical quality and success of all-ceramic crowns.<sup>19-21</sup> Several authors

have tried to define what constitutes clinically acceptable marginal openings. Christensen<sup>17</sup> evaluated the fit of sub- and supragingival margins with a group of dentists and judged that the least acceptable marginal discrepancy in visually accessible surfaces was 39  $\mu\text{m}$ . Lofstrom and Barakat<sup>18</sup> used a scanning electron microscope to measure the supragingival margins of crowns that had been evaluated as precise by several dentists. They reported marginal discrepancy values within a range of 7 to 65  $\mu\text{m}$ .<sup>17,18</sup> Many in vitro studies have shown that CAD/CAM systems can achieve good marginal precision.<sup>22-24</sup>

Long-established recommended manufacturer guidelines require that horizontal marginal finish lines should be prepared

for zirconia restorations.<sup>14</sup> A crown with precise margins has fewer problems, connected to the rate of cement dissolution and of microleakage<sup>25</sup> and a reduced risk of inflammation of vital pulp.<sup>26</sup> Poor margins show more plaque retention<sup>27-29</sup> and an increased recurrence of caries.<sup>30</sup> Increased cement thickness due to poor margins seems to lead to a greater risk of fracture of all-ceramic crowns.<sup>31</sup> In vitro results on the fit of all-ceramic CAD/CAM-generated restorations are promising<sup>32-38</sup> and similar to those of metal ceramic restorations.<sup>1</sup> In an in vivo study Biscaro et al<sup>39</sup> assessed the marginal fit of single crowns produced using two CAD/CAM all-ceramic systems, in comparison to more traditional metal ceramic crowns. All teeth were prepared with horizontal finish lines as described by Raigrodski et al.<sup>14</sup> In this study the mean marginal gap values of traditional metal ceramic crowns were 33.42  $\mu\text{m}$ ; the mean values of the two zirconium-oxide based ceramic single crown groups were 35.32  $\mu\text{m}$  and 34.18  $\mu\text{m}$ . The authors concluded that the two zirconium-oxide based ceramic CAD/CAM systems demonstrated similar and acceptable marginal fits when compared to more traditional metal ceramic crowns.

Some authors have advocated for the use of a vertical preparation for zirconia restorations.<sup>40-42</sup> A vertical preparation would allow the use of zirconia restorations in periodontally involved teeth as abutments for fixed prostheses. Moreover, vertical preparations could preserve a maximum amount of sound tooth structure during tooth preparation for fixed abutments: for this reason they might be a less invasive alternative to horizontal margins.<sup>42</sup> This would be true not only for periodontally treated teeth, but also in other clinical conditions such as endodontically treated teeth, vital teeth in young individuals, and teeth affected by caries at the cervical third of the clinical crown.<sup>43</sup> When preparing teeth for porcelain-fused-to-metal crowns with metal margins, in vitro tests have measured smaller marginal openings for vertical tooth preparations than horizontal ones.<sup>44</sup>

The aim of this investigation was to evaluate and compare in vivo the marginal fit of single-unit zirconia crowns made with vertical and horizontal finish lines. The null hypothesis was that the marginal fit of zirconium-oxide based ceramic single crowns prepared with vertical and horizontal finish line would be similar.

## Materials and methods

Eight patients needing extraction of 46 teeth for implant placement were included in this study: all 46 teeth were vital, caries-free, and had never been treated before. None of the patients dropped out or were dismissed. The Clinical Medical Ethical Committee of the University of Padova, Institute of Clinical Dentistry, approved the study. Patient consent was obtained before tooth preparation. One operator accomplished all clinical procedures.

### Dental preparations and impressions

According to a list of randomization,<sup>45</sup> 23 teeth were prepared for a horizontal marginal finish line (group H) as illustrated in previous studies.<sup>14,39</sup> occlusal reduction of 1.5 mm; axial reduction of 1 to 1.5 mm; 1.0 mm wide. The preparations were 360° rounded shoulders located 0.5 mm subgingivally on the facial



**Figure 1** Two teeth prepared with horizontal line preparation of the margins: the preparations were 360° rounded shoulder as described in previous studies.<sup>14</sup>



**Figure 2** Two teeth prepared with vertical line preparation of the margins: these shoulder-less tooth preparations presented an acute, knife-edge margin of the restoration as described in previous studies.<sup>40</sup>

aspect for esthetic reasons and supragingivally on the lingual aspect (Fig 1). In the other 23 teeth, a vertical shoulder-less line preparation of the margins was developed for each tooth as described by Reich et al.<sup>40</sup> Group V: occlusal reduction of 1.5 mm; axial reduction of 1 to 1.5 mm; the vertical finish line located 0.5 mm subgingivally on the facial aspect for esthetic reasons and supragingivally on the lingual aspect on sound tooth structure (Fig 2). In all 46 teeth the internal angles were rounded, and the axial walls were tapered to 10° convergence. Before tooth preparations, an additional irreversible hydrocolloid impression (Xantalgin Select Fast Set; Heraeus Kulzer GmbH &

Co, Hanau, Germany) was made of each tooth. A thermoplastic resin shell (Erkolen; Erkodent, Pfalzgrafenweiler, Germany) was made for each tooth with a thermoforming unit (Erkopress ES-200E; Erkodent) and used as an index to monitor occlusal and axial tooth reductions as the teeth were prepared.

In group H new diamond burs (#6855 314 025; Komet, Gebr. Brasseler GmbH & Co.Kg, Lemgo, Germany) were mounted in a high-speed handpiece under abundant water irrigation at the initial preparation phase. Finishing diamond burs (#8855 314 025; Komet) mounted in a slow-speed handpiece under abundant water irrigation were used to refine the preparations. In group V new diamond burs (#6862 314 012; Komet) were mounted in a high-speed handpiece under abundant water irrigation at the initial preparation phase. Finishing diamond burs (#8862 314 012; Komet) mounted in a slow-speed handpiece under abundant water irrigation were used to refine the preparations.

Impressions were made in the same way as in our previous study:<sup>39</sup> A single gingival retraction cord (GingiAid ZTwist; GingiPak, Belpart Co., Inc, Camarillo, CA) was used before the impression procedures. For the impression phase, 2 mm thick custom impression trays were made with Palatray LC resin (Heraeus Kulzer, Wehrheim, Germany). The impression material (Impregum Penta; 3M ESPE, Seefeld, Germany) was machine mixed (Pentamix; 3M ESPE): part was put into the tray, and part was meticulously syringed all around the tooth to ensure complete coverage of the tooth itself. Five minutes were allowed for setting of the impression material. The impression was removed from the patient's mouth and poured with an American Dental Association (ADA) type IV artificial stone (New Fujirock; GC Corp., Tokyo, Japan), following the manufacturer's instructions. Irreversible hydrocolloid impressions (Xantalggin Select Fast Set) were made of the opposing dentitions, and impressions were poured with an ADA type IV stone (New Fujirock). The definitive and opposing casts were mounted in a semi-adjustable articulator (Whip Mix Corp, Louisville, KY). Provisional crowns were fabricated with polymethyl methacrylate (Jet; Lang Dental Mfg Co, Wheeling, IL) and cemented using eugenol-free provisional cement (Temp Bond NE; Kerr Italia, Scafati, Salerno, Italy). After the scanning procedures, all 46 single crowns with zirconia copings were generated with the Lava system (3M ESPE). The layering ceramic was Lava Ceram (3M ESPE) leaving 360° zirconium-oxide margins for crowns made with both types of preparation (horizontal and vertical).

Table 1 lists all 46 teeth included in the study and their distribution among the two groups. All copings from groups H and V were 0.5 mm thick. One week after preparation and impressions, the temporary crowns were removed, and the teeth were cleaned with pumice powder and rinsed. Before cementation the definitive crowns were evaluated radiographically and visually, and the marginal fit of all of the crowns considered clinically adequate. All crowns from the two groups were cemented with glass ionomer cement (KetacCem, 3M ESPE) following manufacturer's instructions.

### Tooth extraction and specimen preparation

All eight patients in this study followed appropriate hygiene procedures. One month after cementation of the crowns, the 46

**Table 1** The 46 teeth involved in the study and their distribution in the two groups

	Groups	
	Group H (horizontal finish line)	Group V (vertical finish line)
Maxillary central incisors	4	4
Maxillary lateral incisors	3	3
Maxillary canines	4	2
Maxillary first premolars	2	2
Maxillary second premolars	3	3
Mandibular canines	2	2
Mandibular first premolars	2	2
Mandibular second premolars	3	5

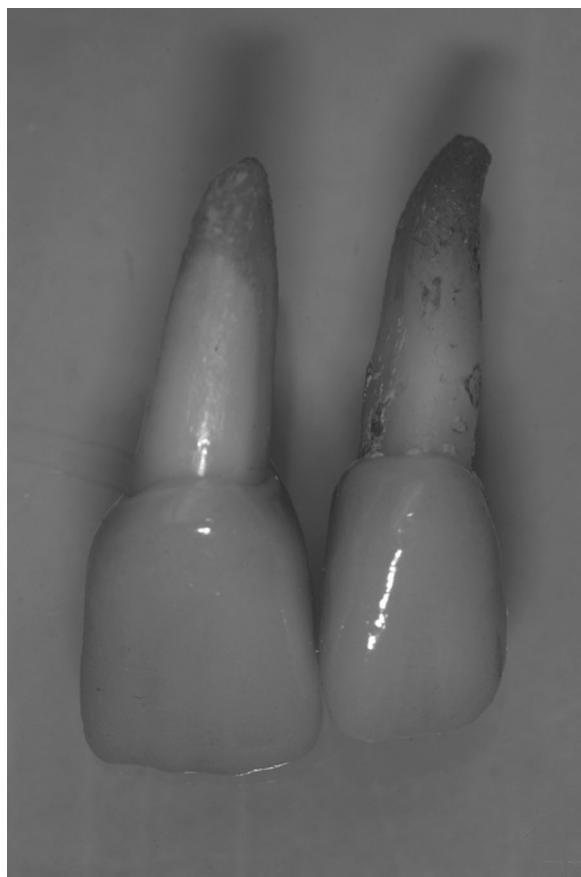


**Figure 3** Two extracted teeth prepared with horizontal line preparation of the margins.

teeth were extracted, using great care to avoid any damage to the restorations (Figs 3 and 4).

### Microscopic evaluation

Microscopic evaluation was conducted with the same method used in our previous study:<sup>39</sup> For marginal gap measurements along vertical planes, four landmarks (mesial, distal, buccal,

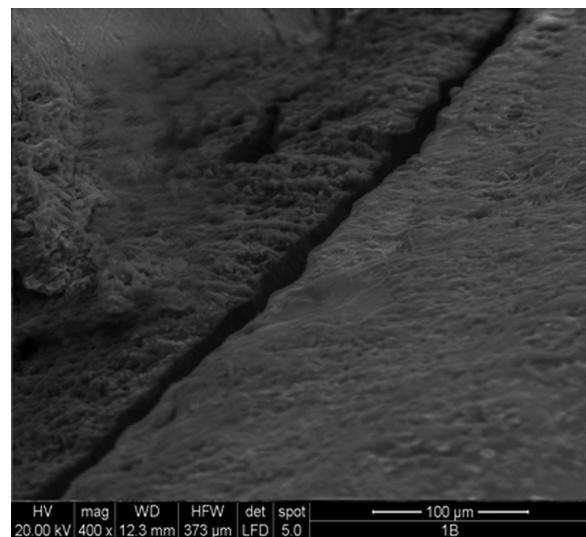


**Figure 4** Two extracted teeth prepared with vertical line preparation of the margins.

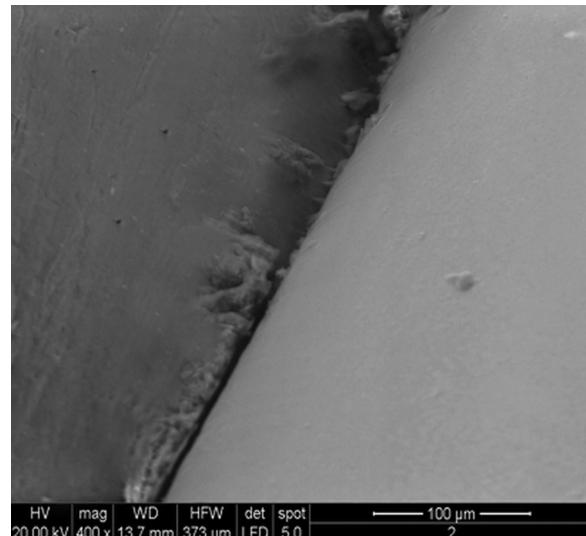
and palatal) at each tooth were defined. Marginal fit was measured at the external point where the zirconia coping met the dental structure.<sup>39</sup> Measurements were performed using a microscope (Axioskop; Zeiss, Oberkochen, Germany) at 50 $\times$  magnification. The Axioskop was connected to a digital camera (DC 200; Leica, Bensheim, Germany), and the QWINLITE program (Leica) was used for measurement. The vertical openings were recorded in microns. The marginal fits of each single crown of two groups were measured. On completion of microscopic evaluation, representative specimens from each group were prepared for environmental scanning electron-microscope (ESEM) evaluation (FEI Quanta 200, Hillsboro, OR) to evaluate the marginal gaps of different groups (Figs 5 and 6) qualitatively. All procedures were performed by two investigators: the first prepared the specimens, while the second was blind to the treatment and performed the data analysis.

### Statistical analysis

To compare the overall gap at the finish line between the vertical and horizontal finish line groups, all measurements at the four landmarks (mesial, buccal, distal, lingual/palatal sites) were considered together. The null hypothesis was that there would be no difference in the gap at the finish line between the two



**Figure 5** ESEM analysis at 400x of a group H (horizontal preparation) specimen.



**Figure 6** ESEM analysis at 400x of a group V (vertical preparation) specimen.

types of preparation. Graphic visualization and Shapiro-Wilk test confirmed that the continuous outcome variable (gap at finish line) was not distributed normally ( $p < 0.001$ ). Therefore, both median and interquartile ranges (Iqr) were reported as descriptive statistics. The comparison of the gap between the two types of preparation was performed with a nonparametric test (two-sample Wilcoxon rank-sum test) with a level of significance fixed at  $p < 0.05$ .

The reliability of measurements was tested by comparing 99 values measured from the same operator twice, at a distance of 1 week (198 total measurements). The Intraclass Correlation Coefficient (ICC) reached a value of 99%, defining a high reliability. All data were analyzed with STATA12 (StataCorp LP, College Station, TX).

**Table 2** Descriptive statistics (median and interquartile range) of the gap measurements at 4 landmarks in the 2 preparation groups

	Preparation groups	
	Group H (horizontal finish line) N = 23	Group V (vertical finish line) N = 23
Mesial Median (Iqr), $\mu\text{m}$	35.39 (0.33)	35.36 (0.21)
Distal Median (Iqr), $\mu\text{m}$	35.44 (0.55)	35.34 (0.43)
Buccal Median (Iqr), $\mu\text{m}$	35.45 (0.19)	35.44 (0.66)
Palatal/lingual Median (Iqr), $\mu\text{m}$	35.55 (0.33)	35.54 (0.43)

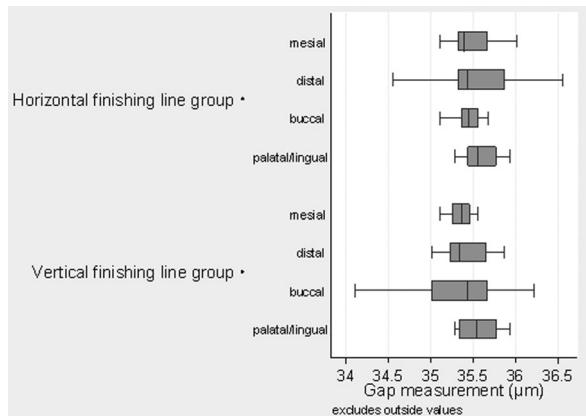
Iqr is interquartile range

**Table 3** Descriptive statistics of the overall gap measurements in the two preparation groups and level of significance of the difference (two-sample Wilcoxon rank-sum test) between the preparation groups

	Preparation groups		Comparison between the two groups ( <i>p</i> value*)
	Group H (horizontal finish line) N = 92	Group V (vertical finish line) N = 92	
Overall gap Median (Iqr), $\mu\text{m}$	35.45 (0.33)	35.44 (0.40)	0.0872

<sup>a</sup>Two-sample Wilcoxon rank-sum (Mann-Whitney) test;  $\alpha$  level < 0.05

Iqr is interquartile range

**Figure 7** Box plot of the gap measurement at four landmarks in the two preparation groups.

## Results

Median and interquartile range of the gap at the finish line of the two groups measured at the four landmarks are reported in Table 2 and represented with a box plot in Figure 7. For both preparation groups, the four values recorded in mesial, buccal, distal, and lingual/palatal sites were considered together to evaluate the overall lack of fit of FDPs for a total of 92 measurements each (184 total measurements).

In the group with a horizontal finish line preparation (group H), the median value of the gap was  $35.45 \mu\text{m}$ . The median value of the gap amounted to  $35.44 \mu\text{m}$  in the vertical finish line group (group V) (Table 3). The difference between the two groups was not statistically significant.

## Discussion

The results of this study supported the null hypothesis: the amount of gap at the finish line was not statistically different in the two preparation types. Within the limitations of this in vivo study, due to the small number of specimens tested, it was concluded that the marginal fit of single-unit zirconia crowns made with a vertical finish line was similar to the marginal fit of single-unit zirconia crowns made with the more conventional horizontal finish line, thus confirming the results of previous studies.<sup>1,38,39</sup> Microscope results were in agreement with observations made from the ESEM. Vertical preparation would allow the use of precise zirconia restorations in periodontally involved teeth as abutments for fixed prostheses. Moreover, preserving a maximum amount of sound tooth structure during tooth preparation for fixed abutments, as is commonly done in vertical preparations, might be a less invasive choice compared to crowns made with a horizontal margin. This would be true not only for periodontally treated teeth, but also in other clinical conditions such as endodontically treated teeth, vital teeth in young individuals, and teeth affected by caries at the cervical third of the clinical crown.<sup>43</sup>

This study had further limitations. First, only one zirconium-oxide-based ceramic CAD/CAM system was used. In this study only vertical gaps were checked: to assess the accuracy of the fit of crowns, measurements must be made on both vertical and horizontal planes. The teeth with crowns were extracted very early, only 1 month after final cementation. Additional clinical investigation would be necessary to evaluate the effect of different tooth preparation designs<sup>46,47</sup> with different total occlusal convergence angles on margin distortion: in this study the axial walls were slightly tapered to  $10^\circ$  convergence for both types of preparation. Only one cement was used. Additional studies should be performed with different cements and

cementation techniques.<sup>48</sup> Also, all the crowns included in this study had 360° zirconium-oxide margins: the zirconia margins, when a vertical finish line preparation is used, are thinner than the zirconia margins obtained when a horizontal finish line preparation is used. Therefore, these thinner margins may be more easily altered during various clinical phases, for example during cementation<sup>14</sup> or scaling procedures.<sup>49</sup>

Within its limits, this study proved that it is possible to use CAD/CAM systems to achieve good *in vivo* marginal fit for single-unit crowns made with horizontal and vertical finish lines of preparation with the advantages of homogeneous standardized materials.<sup>13</sup> On the other hand, additional research must be performed; for example, concerning the precision of horizontal and vertical finish lines in the case of multiple dental restorations.

## Conclusions

Within the limitations of this study, it was concluded that the gaps at the finish line of zirconium-oxide-based ceramic CAD/CAM crowns with vertical and horizontal finish lines presented no difference in the two types of preparation.

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