Comparison of marginal fit of Lava CAD/CAM crown-copings with two finish lines

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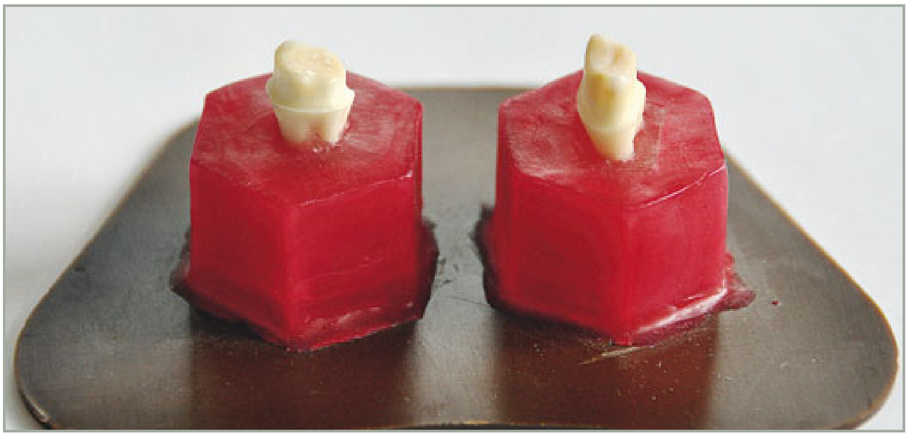

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Abstract

Purpose: Marginal fit is valued as one of the most important criteria for the clinical quality and success of all-ceramic crowns. The aim of this *in vitro* study was to investigate the marginal fit of Lava Zirconia crown-copings on chamfer and shoulder preparations.

Methods: Two acrylic model teeth were selected to simulate the clinical preparations: one molar was prepared with a chamfer finish line (C) and one premolar was prepared with a rounded shoulder finish line (RS). Each resin model was duplicated 10 times using silicon-based impression material and poured in type IV dental stone for the fabrication of working dies. A total of 20 copings were divided into two groups (n = 10 for each finish line). Fifty measuring locations were chosen randomly along the margin on the dies and the gap width – vertical marginal discrepancy – was measured under a light microscope with a magnification of ×100. Measurements were made without cementation. The mean marginal gap widths and standard deviations were calculated and a one-way analysis of variance (ANOVA) was performed for different types of preparations in order to detect differences ($\alpha = 0.05$).

Results: The mean marginal gap was 30 ± 3 µm for the C group and 28 ± 4 µm for the RS group. The one-way ANOVA showed no statistical significant difference between the two groups ($P = 0.23$).

Conclusions: Within the limitations of this study, the marginal discrepancies were all within the clinical acceptable standard set at 120 µm. Chamfer and shoulder preparations did not show differences regarding the gap dimension.

Clinical significance: Bur design is an easily selected parameter before natural tooth preparation. Both tested finish lines are able to help clinicians in obtaining acceptable marginal fit values for the investigated zirconia copings.

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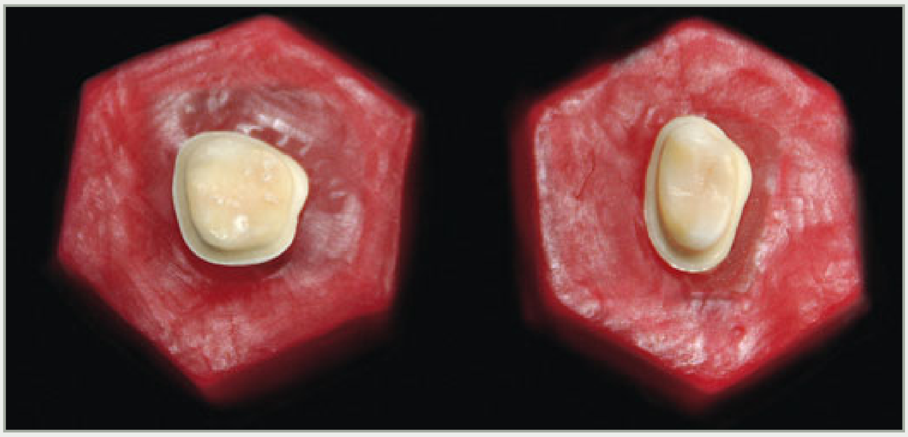

Introduction

Computer-aided design/computer-aided manufacturing (CAD/CAM) systems allow the development of dense alumina and zirconia-based, high-strength ceramic crowns or bridges:[1] these products are considered extremely biomimetic (due to the absence of a metal framework),[2] respectful of the periodontal tissues (through the juxta or supragingival positioning of the preparation margins)[3] and exhibit superior mechanical properties compared to conventional glass/feldspathic ceramic materials.[4] In particular, zirconia-based restorations have been used for the rehabilitation of anterior and posterior teeth with acceptable survival rates (at 10 years: 67% for three- to five-unit fixed partial dentures; at 5 years: 88% for single crowns).[5,6]

The clinical performance of prosthetic restorations is associated, among other factors, to the accuracy of fit. Poor marginal adaptation leads to open margins; plaque accumulation might increase the risk of recurrent caries,[7] pulp inflammation in vital abutments, and periodontal disease.[3] Moreover, the presence of marginal discrepancies exposes the luting agent to the oral environment: the larger the gap size, the faster the rate of cement dissolution.[8] The topic of internal and marginal fit has been explored in a wide number of studies, embracing different types of prosthodontics solutions, from indirect restorations like inlays or onlays to veneers or fixed partial dentures.[9-12]

American Dental Association (ADA) Specification No. 8 states that the luting cement film thickness for crown restorations should not be more than 25 µm when using a Type I (fine particle size) luting agent, or 40 µm with a Type II (medium particle size) luting agent. As a clinical goal, it has been suggested that marginal gaps of cemented restorations should range from 25 to 40 µm. However, marginal openings within this range are seldom achieved clinically.

The cervical finish line is considered a fundamental variable controlled by the clinician during tooth preparations for complete crowns; a precise margin design allows proper seating and could affect the cervical adaptation of restorations. Modifications of cervical finish line types may improve vertical marginal discrepancy.[13] Recently, Bottino et al[13] found the best cervical adaptations (vertical marginal discrepancy in the range of 46 to 70 µm when applying an internal relief) using a chamfer configuration with respect to 90- or 135-degree shoulder finish lines (in the range of 66 to 113 µm); unfortunately they used full metal crowns in their study, which are not frequently delivered in clinical practice and, of course, are not subjected to additional laboratory steps like veneering.[13]

For traditional metal-ceramic restorations some precise indications on the preparation margin design are available: for example, it was proven that the chamfer finishing is subject to distortion during the porcelain firing process,[14] and that proper space/thickness for framework and veneering materials could be compromised with such a design.[15] In case of metal-ceramic restorations, the knife-edge margin type has traditionally been mainly suggested for preparations following root amputations or in the presence of deep cusp fractures.[15] On the other hand, less attention was paid to the effect of different geometries of the preparation margins on the final adaptation of CAD/CAM, high-strength ceramic restorations.

Aim of the study

The purpose of this *in vitro* study was to examine the influence of the marginal preparation design on the precision of fit of zirconia crown-copings. The tested null hypothesis was that the finish-line configuration did not influence the marginal fit of indirect zirconia copings produced by a specific CAD/CAM system.

Materials and methods

Selection of the materials

The Lava All-Ceramic System (3M ESPE) was the CAD/CAM system selected to produce the copings. It employs pre-sintered blocks (Lava Frame Zirconia blanks, 3M ESPE) of high-density zirconium-dioxide, a polycrystalline ceramic free of any glass component whose density and resistance are superior to the glass-infiltrated materials.[4] The pre-sintered material looks soft and chalky, allowing for fast and accurate milling. Software preventively calculates the shrinkage of the material subsequent to the sintering procedure.

Sample preparation

Two maxillary artificial teeth, made by acrylic resin, were selected to perform a simulation of the clinical preparation for a full-crown. The axial (1.0 to 1.5 mm) and occlusal reductions (1.5 to 2.0 mm) of both teeth were carried out according to the guidelines of the manufacturer.

Then, by means of a bur mounted on a high-speed handpiece, the two marginal preparation designs examined in this study were traced: a shoulder with rounded axiogingival internal line angle (RS) on the molar and a chamfer (CH) on the premolar. The two designs represent those commonly suggested in the preparation of teeth to be restored with an all-ceramic restoration; the cervical finish line width was approximately 0.8 mm. The employment of a parallelometer increased the precision of the preparations performed; medium-grit followed by fine-grit diamond burs were used to provide smooth finished margins.

Each prepared tooth (Figs 1a and 1b) was replicated 10 times by means of a vinyl poly-syloxane elastomeric impression material (Elite HD; Zhermack); working dies were made in extra-hard chalk material (type IV dental stone) (Elite Rock, Zhermack). Finally, The 3M manufacturing center scanned the models (non-contact, optical scanner, Lava ScanST, 3M ESPE), designed the zirconia copings using the proprietary software, and performed the three-dimensional milling of pre-sintered blocks (Lava Form Milling System, 3M ESPE) and final sinterization (Lava Furnace 200, 3M ESPE).

The 20 copings obtained (n = 10 for each margin preparation design) were cleaned with steam and dried with compressed air and finally seated on their respective working models (Figs 2a and 2b). Copings that had macroscopic deficiencies at a preliminary visual examin-

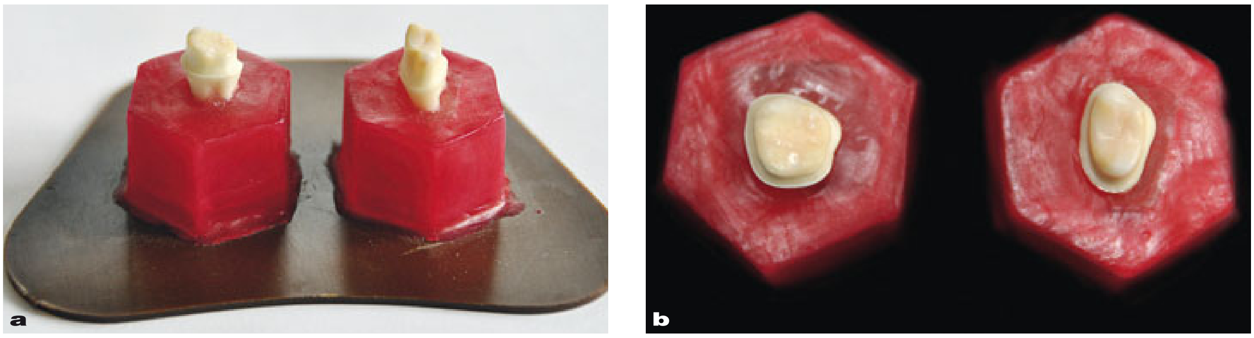

Fig 1 Acrylic molar and premolar master models with chamfer and shoulder configurations, respectively. **(a)** frontal and **(b)** top views.

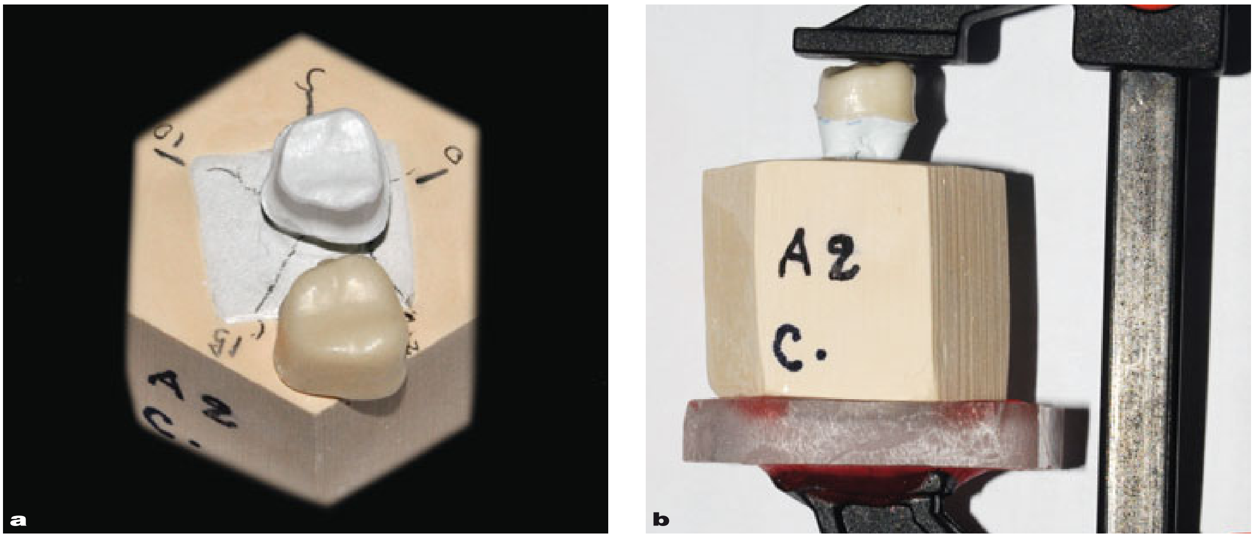

Fig 2 Coded working models with their own zirconia copings, **(a)** before and **(b)** after seating for evaluation of marginal discrepancies.

ation were remade. Luting was avoided in order to decrease the number of variables considered in the measurements.

Vertical discrepancy measurement at the tooth – restoration interface

The measurements performed in the present study evaluated the vertical marginal discrepancy existing between the zirconia coping and the preparation edge, as described by Homes et al.[16] Fifty sites were randomly marked along the circumference of each sample, setting an adequate number of points in which the measurements were performed.[17] A 3 kg constant pressure was applied on the copings during the measurements by means of a calibrated spring compressed by a clamp. This device allowed to standardize the measurements and to maintain the copings on the chalk models. Finally, the gap width was measured perpendicular to the coping/die assembly by a single operator, using a 100X optical microscope (Leica MZ12).

Statistical analysis

The statistical software SPSS 17 (SPSS Inc) was used to analyze the experimental data. After computing mean and SD of the samples, the analysis of variance (ANOVA) test was employed to identify any difference between the two examined groups. Then, the post-hoc Student *t* test and Tukey-Kramer test were used to identify the significant values. The level of significance was set at 95%.

Results

Means, range and standard deviations of the vertical marginal discrepancy measured for the two analyzed groups are shown in Table 1. ANOVA results are shown in Table 2. A graphical representation of results is available in Fig 3. No statistical significant differences existed among the tested groups ($P = 0.2372$); however, lowest gaps were obtained in the copings fitting a shoulder preparation (22.8 to 34 μm vs 27.6 to 35 μm). The chamfer group showed a smaller standard deviation of values (2.8 vs 3.7).

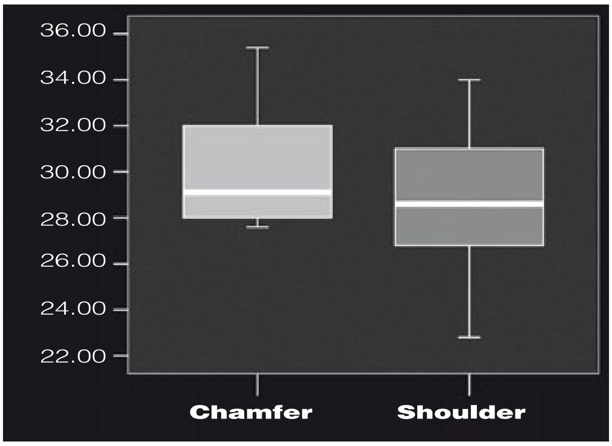

Fig 3 Boxplot – graphical representation of results.

Table 1 Means, range and standard deviations of the vertical marginal discrepancy measured for the two analyzed groups.

Group	Count	Mean ± SD (μm)	Range (μm)
Chamfer	10	30.2 ± 3	27.6–35.4
Shoulder	10	28.4 ± 4	22.8–34.0

Table 2 ANOVA table for vertical marginal discrepancy

Source	DF	Sum of squares	Mean square	F Ratio	Prob>F
Design	1	16.5620	16.5620	1.4952	0.2372
Error	18	199.3800	11.0767		

Discussion

Precision of the restoration and clinical limits

The precision of prosthetic restorations is linked to the chance of restoring an anatomic continuum between the residual surfaces of the tooth (prepared or not) and the manufactures. In this sense, the gaps at the interface should be none or minimal and, if present, they should be filled by the luting materials. Considering full crowns, McLean and von Fraunhofer[18] suggested 120 µm as the maximum marginal gap that could be clinically acceptable. One thousand restorations were examined 5 years after the cementation: those considered in accord with the study criteria showed a marginal gap equal or smaller than 120 µm. Nevertheless, according to McLean, marginal gaps smaller than 50 µm cannot be detected clinically.[18]

Margin adaptation and CAD/CAM

Several clinical and manufacturing variables were linked to the marginal or internal fit of high strength full ceramic crowns: the CAD/CAM system employed has a key role, since the number and the quality of steps of development of the superstructure[19] bring different values of marginal fit, even if the geometric features of the cast are the same. A recent study by Martinez et al[20] showed that In-Ceram Zirconia (VITA Zahnfabrik; 29.98 ± 3.97 µm) had an higher absolute marginal discrepancy than In-Ceram YZ (VITA Zahnfabrik; 12.24 ± 3.08 µm), Cercon (Dentsply; 13.15 ± 3.01 µm) or Procera (Nobel Biocare; 8.67 ± 3.96 µm). The aforementioned systems have specific manufacturing processes, such as the initial sintering status of zirconia (already sintered for In-Ceram Zirconia), the scanning method (wax pattern acquiring for Cercon, or chalk model acquiring for the other systems), scanner type (contact scanner for Procera, optic or laser scanner in the other systems), realization type (pressing on enlarged mold for Procera, CAM milling for the other systems). The infiltration of lanthanum glass subsequently to the milling out of the coping was considered responsible for a poorer marginal fit of the In-Ceram Zirconia group. Moldovan et al reported significantly different internal gaps (between the intaglio surface and the tooth) using two different milling methods of zirconia blocks (dry: 69 to 94 µm; or wet ground: 116 to 145 µm).[21] In another study, the CAD/CAM technique of the Procera system was reported to be better than a mechanical manufacturing process of zirconia (Ceramill pantographic systems; Amann Girrbach).[22]

Fit, tooth preparation and finishing line

The second group of factors that can influence the marginal precision is dependent on the cast preparation geometry.[23-26] In particular, an occlusal convergence of the axial walls of 12 degrees allowed the reduction of the superstructure vertical gap of single crowns (46 to 50 µm), with respect to angles of 4 degrees (67 to 91 µm) and 8 degrees (67 to 82 µm).[24] In addition, it was suggested that by increasing the depth of the finishing line (degree of misalignment of planes in the passage between the proximal and buccal/palatine walls), it is possible to improve the marginal gap of the substructure, with respect to preparations with margins approximately positioned on the same plane.[25-26]

Clinicians have complete control on the finishing line of the preparation (since it depends on the preliminary choice of a particular shape of the bur), while the values of other variables are less predictable (ie, the occlusal convergence angle or the preparation depth). In the present study, the null hypothesis was accepted: no significant difference was identified between the average marginal fit of a chamfer preparation (30.2 ± 2.8 µm) and that of a rounded shoulder preparation (28.4 ± 3.7 µm). With regards to the zirconia framework of single crowns, some researches confirm our result, even if conducted with different CAD/CAM systems,[27-29] while others indicate greater marginal fit with the use of a particular finishing line. For example, with the Procera AllCeram, the shoulder preparation helped obtaining smaller absolute vertical marginal discrepancy than those obtained with a chamfer (71 ± 42 µm vs 143 ± 49 µm);[30] on the contrary, with Cercon the chamfer had smaller values than the shoulder for 15-degree convergence angles, while, on the other hand, no difference was evidenced for 20-degree angles.[31]

It is possible that the specific features of each CAD/CAM system allow a particular finishing line to be reproduced faithfully, and it is more difficult to give general indications; moreover, despite according to Quintas et al,[27] the choice of the manufacturing system has a major influence on the final precision of the restoration, the knowledge that the finishing line would be better reproduced by the system would be an important decision by the clinician in order to optimize the marginal fit.

Finishing line and fracture resistance

In case there is no difference in terms of marginal fit relative to two different finishing lines, it is possible to make a selection considering other parameters. A recent study focused on the interaction between the finishing line design and the fracture resistance of zirconia,[32] but, up to now, no information has been available for Lava. For ceramic-covered zirconia crowns, Abhouselib did not find any association between the margin type and the resistance to fracture or fatigue; however, a shoulder configuration was not analyzed.[33] The heterogeneity of the results and the restricted number of investigations should promote a deeper investigation of this topic.

Lava restorations marginal discrepancy

The values obtained in the present study, regardless of the finish line, are in agreement with previous data regarding copings or crowns produced with the CAD/CAM Lava system: the vertical discrepancies reported by other studies are among 24.6 ± 14.0 µm[34] and 62.22 ± 1.78 µm[35]. In case of bridge frameworks, the marginal fit values in the preluting phase reported by Gonzalo et al were lower than 80 µm.[36] In all of these cases, it is clear that the clinical limit of marginal fit acceptability (120 µm) is widely respected. It is necessary to underline that the cited studies were conducted according to several methods, with differences related to the number of measurements or techniques employed (such as luting procedure, selection of the copings, veneering, measured distances: vertical marginal discrepancy or absolute marginal discrepancy); this can explain the oscillation of the values. The minimum number of measurements (50) defined by Groten et al, in order to obtain a full evaluation of the marginal fit along the circumference of the coping, was respected in the present study.[17]

Study limits

The evaluation of the marginal gap on luted crowns and after aging, the influence of the finishing line on the internal adaptation of the restoration or on its resistance, are topics that should be evaluated more accurately in further studies. Some differences between finish lines (including the feather-edge design) may also affect retention or adhesion[37] of zirconia-copings to abutments, or the ease of excess cement removal.

Conclusions

- Both rounded shoulder and chamfer finish lines returned clinically acceptable marginal adaptation values, expressed as vertical marginal discrepancy, far below the limit set at 120 m.
- Since marginal adaptation was excellent with both rounded shoulder and chamfer finish lines, a clinical selection between those two marginal preparation designs should be performed based on other variables, ie, the resistance to fracture of crowns with a specific finishing geometry, to be explored in future studies.

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