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Research Article

Marginal Gap Evaluation in Non-Cemented Crown Restorations

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Abstract

The vertical marginal gap should be regarded as the most critical in crown margin evaluation. The purpose of this study was to compare the marginal gap of crowns made from different materials and technique. Comparisons were made among six groups (n=8). Conventional metal ceramic (MCc) crowns; modified metal ceramic (MCm) crowns; lithium disilicate reinforced ceramic crowns (CDis); leucite reinforced ceramic crowns (CLeu); leucite fluoride-apatite reinforced ceramic crowns (CLeuF); polymer crowns (CCer). The crowns from 48 bovine teeth were cut and 15 mm long regular and similar roots were obtained, endodontically treated and reconstructed with a metal post plus composite resin core. Impression from each specimen was made using a polyether and all restorations had the final form of a premolar with axial thickness of approximately 1 mm in the cervical and middle third and 2 mm in the occlusal surface. Each crown was fitted in its preparation and the marginal gap was measured under stereomicroscope examination (×40). A total of 16 measures were obtained from each tooth (4 in each face). Data were submitted to 1-way ANOVA statistical analysis and significant differences among the groups were not found. In conclusion, the selection of the crown restorative system should not be based on the marginal gap only as all systems presented similar results within the 100 µm limit clinically acceptable.

Keywords: Marginal gap; Cement films; Ceramic crowns

Introduction

Esthetics and resistance to fracture are two of the main determinants of the success of a restoration; the third is marginal adaptation [1]. The vertical marginal gap is the space between the marginal surface of the restoration and the tooth finish line, has the most clinical relevance and should be regarded as the most critical in crown margin evaluation [2]. There is no agreement on definition of marginal gap values, [3] with reported values ranging from 3.7 to 174 µm, [1,2,4-8] nor on a common method of evaluation [3]. The American Dental Association states that the proper fit of a fixed prosthesis ranges from 25 to 40 µm, [9] but it is very difficult to reach such a goal using most of the current manufacturing technology [10]. The marginal gap level of 100 µm was defined as clinically acceptable [11] and the 120 µm was considered the maximum tolerable marginal opening [12]. The ideal gap should be small enough to prevent ingress of saliva and/or lactic acid, which is the byproduct of bacterial metabolism [13]. Gap margins of poor quality with measures higher than the 0.75 µm diameter of the Streptococcus mutans [14] might lead to cement dissolution, marginal discoloration or staining, microleakage, and secondary caries [15].

The marginal accuracy is significantly influenced by tooth preparation design, material characteristics, fabrication method, gap measuring method, and other factors [1,5,16-22]. The investigation of the marginal fit is so critical that three studies evaluating the same materials and using the same method presented three different results [4,23,24]. Concerning to the marginal fit the quality of tooth preparation and impression steps are clinicians-dependent while the quality of the indirect restoration is technicians-dependent. The fully digital fabrication method may provide better margin fit than the conventional method [2,25,26] as it eliminates most of the steps clinician/technician-dependent [27]. The challenge is to provide clinicians with a technique to asses a gap smaller than 100 µm [28] as the reading accuracy of the marginal gap was shown to be operator-dependent and improved with ×4 optical magnification for clinicians [29]. In the clinical situations the marginal fit of restorations is directly evaluated by visual observation using or no an explorer [28,30,31] and through radiographs. A sharp explorer can identify an opening of 36 microns with 95% of the people using it. Dull explorers have difficulty in detecting marginal gaps of this size [32,33]. Higher marginal gaps could contribute to the zinc phosphate cement dissolution, hydrolytic degradation of resin cements or bonding hydrolysis when adhesive cementation is used [15,34-36].

Different crowns restorations obtained from different methods have been used in the search for the ideal material that would combine strength, esthetics and accurate marginal fit. As a functional property, the lower the marginal gap the lower the exposition of the cementing agent to the oral environment. The use of CAD-CAM technology significantly increased in the last decade due to their esthetic, mechanical and biocompatibility properties [2,4,24,37,38] by eliminating or reducing potential procedures for dimensional inaccuracies [20].

Thus, purpose of this study was to compare the marginal gap of crowns made from different materials and technique. The null hypothesis was that there was no difference in the marginal gap

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among the used materials.

Material and Methods

Comparisons were made among six groups (n=8). Conventional metal ceramic (MCc) crowns with a metal coping and feldspathic ceramic; modified metal ceramic (MCm) crowns, as in the control group, but with aluminum-reinforced ceramic in the buccal cervical area (collarless); ceramic crowns reinforced by lithium disilicate (CDis); ceramic crowns reinforced by leucite (CLeu); ceramic crowns reinforced by leucite fluoride-apatite (CLeuF); polymer crowns (CCer). All materials used were manipulated in accordance with manufacturers' recommendations. Composition and manufacturer information are listed in Table 1. Out of 200 bovine teeth stored in 0.2% Tymol solution for up to a month, 115 with regular and similar roots were selected. They were sectioned with a double-sided diamond disc (KG Sorensen, Barueri, Brazil) to obtain roots 15-mm long.

Then, 48 roots with similar volume (cervical mesiodistal diameter of 5 to 6 mm, and buccolingual diameter of 6 to 7 mm), shape, and canal diameter were chosen. Root canals were filled with gutta percha and Fill Canal cement (Technew Com. Ind. Ltda, Rio de Janeiro, Brazil) and then prepared with a 1.59-mm diameter cylindrical rotary cutting instrument (Fast steel bur 1/16, Twill, São Paulo, Brazil) to a depth of 10 mm, cleaned with hydrogen peroxide, washed, and dried with paper points. Cylindrical NiCr (Durabond MS, Marquat S/A, São Paulo, Brazil) cast dowels, 12-mm long, received a circumferential groove to increase mechanical retention for a composite resin core and were cemented in the canal, after being air-abraded with aluminum oxide (N. Martins e Teixeira Ltda, S˜ao Paulo, Brazil), with zinc phosphate cement (Vigodent S/A, Rio de Janeiro, Brazil). After acid etch and adhesive application cores were built with composite resin (Z250, 3M ESPE, São Paulo, Brazil) placed in three increments. Each increment was polymerized for 20 seconds, under at least 500 mW/cm2 (Optilight II, Gnatus, São Paulo, Brazil) at a distance of 3 mm. Cores were prepared at high speed using a 2143 (80 µm) and finished at low speed using a 30-40 µm diamond rotary cutting instrument (KG Sorensen). The final characteristics of the preparations were: 6º axial convergence, 1-mm rounded shoulder, and rounded internal angles. The finished core was 3-mm high in the central area and about 3.5-mm high in the cuspal areas. Shoulder width was controlled using the rotary instrument (1.2-mm diameter) as reference, and axial convergence was checked using a device previously calibrated. Impressions of the preparations using polyether (Impregum) were made after 10 days of storage in saline solution to allow hygroscopic expansion of the composite resin core. Manufacturers' instructions were followed for all restorative systems used, and all restorations had the final form of a premolar with axial thickness of approximately 1 mm in the cervical third and 2 mm in the occlusal surface checked with a caliper (Figure 1).

Each crown was fitted in its preparation and macroscopic assessed according to clinical practice under visual inspection using a ×3.5 dental loupes (Lupa Bioart 3.5X) and the dental explorer at a focal distance of approximately 30 cm [29]. Only the crowns approved by the single examiner were submitted to the stereomicroscope investigation 39 at ×40 magnification (Modelo LEICA MS 5 – Leica Microscopy Systems Ltd – Heerbrugg - Switzerland). The marginal gap line from each tooth face was linearly divided in 4 areas. The larger gap from each area, measured from the finish line to the restoration margin, [16] was recorded thus resulting in 16 measures per tooth. The mean value from 16 measures per tooth was considered for the marginal gap calculation for each group. Within each group a total of 128 measures were obtained resulting in 768 measures for all the 6 groups [25,40]. Data were submitted to 1-way ANOVA at the 95% confidence level.

Table 1: Characteristics of restorative materials.

Material	Composition	Manufacturer
Durabond MS	Ni-Cr	Marquat S/A – São Paulo - Brazil
Noritake	Feldspatic ceramic	Noritake Kizai Co. Ltda - Japan
Vitadur	Aluminum reinforced ceramic	Vita Zahnfabrik, Sackingen, Germany
IPS Empress II	Lithium di silicate reinforced ceramic	Ivoclar Vivadent – São Paulo - Brazil
Cergogold	Leucite reinforced ceramic	Degussa – São Paulo - Brazil
IPS d.Sign	Leucite fluoride-apatite reinforced ceramic	Ivoclar Vivadent – São Paulo - Brazil
Targis	Laboratory composite resin	Ivoclar Vivadent – São Paulo - Brazil

Table 2: Marginal gap original and mean values (µm); SD: Standard Deviation.

	Original values								Mean (SD)
GROUP	1	2	3	4	5	6	7	8	
MCc	62.3	75.1	75.4	85.7	66.6	72.6	95.2	66.1	74 (11,0)
MCm	95.2	81	90.3	130	87	89.3	100.9	142.8	102 (22,2)
CDis	36	61.2	59.9	85.9	115.8	107.8	103.7	128	87 (32,1)
CLeu	99.8	117.9	114.8	89	133	75.6	106	57.1	99 (24,5)
CLeuF	52.5	126.4	42.7	108.3	91.9	63	71	89.8	80 (28,5)
CCer	63	156.5	196.9	117.3	52.7	85.2	36.3	98	100 (54,5)

Results

The marginal gap values are presented in the Table 2. ANOVA statistical analysis showed no significant difference between the groups (Table 3).

Although not significantly, the group MCc presented the lowest mean value of marginal gap among all the groups, followed by the CDis and CLeuF with similar values, and the lowest mean values were presented by the MCm, CLeu and CCer. The Figure 2 shows the marginal gap original values in the increasing order and mean values from all the groups.

Amplified images showed marginal irregularities from both the teeth and crown restorations (Figure 3).

Discussion

The most approximation to the clinical conditions was tried when performing the current study. Thus, bovine teeth were used, one preparation was made for each restoration and all clinical and laboratory protocols were followed. Direct view technique is the most commonly used method for marginal inspection and recorded the most reproducible results among different studies [41]. Before the stereomicroscope analysis the marginal fit evaluation was made direct on the tooth under visual inspection using the explorer and a ×3.5 loupe (Lupa Bioart 3.5X). As the statistical analysis did not show significant difference between the groups the null hypothesis

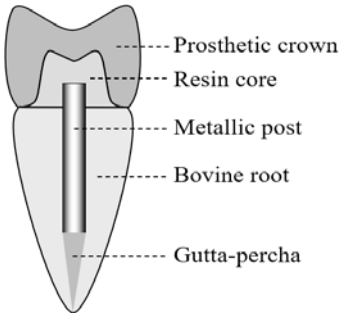

Figure 1: Schematic illustration of the specimens.

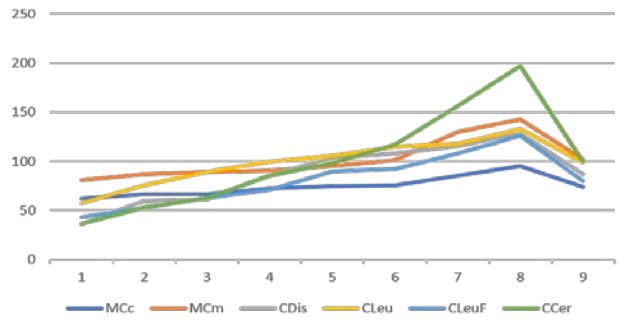

Figure 2: Marginal gap original values (µm) in increasing order. Record 9 represents mean values.

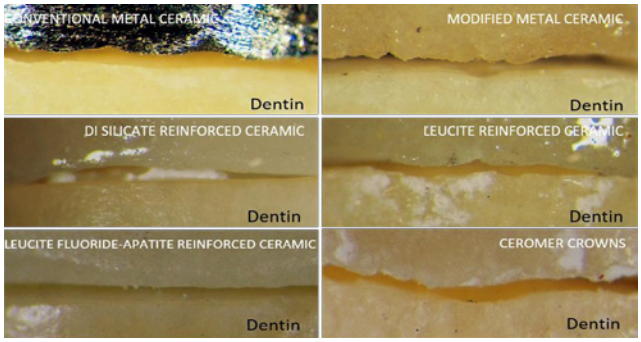

Figure 3: Illustrative marginal gaps from all the restoration systems.

was accepted.

In general, data found in the literature are used as reference to validate and/or to compare results from researches that use similar method and materials. Marginal gap ranging from 25 to 40 µm was stated as proper by the ADA No. 8.9 but cement films in the range of 25-50 µm are seldom to be obtained [42]. The practical range for clinical possibilities and acceptability of internal fit may vary from 50 to 100 µm [6,11] and the 120 µm was stated as the maximum clinically tolerable marginal opening [12]. An overall review of the data retrieved for marginal gap showed that 94.9% of the values measured were less than or equal to 120 µm. In the present study although the teeth preparation was made by one operator and the crown restorations made by a single technician all the groups presented mean values within the 100 µm clinically acceptable. Many specimens (33%) showed values higher than that limit, ranging from 102 to 196 µm although. In clinical conditions marginal fit can be most accurately

Table 3: Analysis of Variance between the groups.

Variation Source	Sum of Squares	DF	Mean Square	(F)	Prob. (Ho)
Between groups	5304.094	5	1060.819	1.06	39.86%
Residuous	42188.5	42	1004.488		
Total	47492.59	47			

assessed using a combination of explorer and visual examination.28 A sharp explorer can identify an opening of 36 microns with 95% of the people using it [32] but most of the explorers are likely to be not sharp and so not capable of detecting larger marginal gaps. Mclean et al. [12] examined the marginal fit of 1000 fixed restorations over a 5 years period and indicated that marginal gap less than 80 µm is difficult to detect under clinical conditions. Under visual inspection in the oral environment the preparation may appear appropriate but the magnification showed poor quality of the finish line, which is a factor operator-dependent. Hence, clinicians must carefully attempt to the finishing of the preparation, mainly at the finish line. Tooth preparations refined with finishing burs may favor the placement of restorations with the smallest marginal gap [23].

In general, the marginal discrepancies at each marginal location were influenced by the fabrication procedure [16]. Four parameters were found to influence marginal adaptation: finish line configuration, value of the predefined cementing space, veneering process, and cementation [1]. In the present study, six restoration systems were evaluated and the appropriate selection would depend on clinical conditions, functional parameters, patient expectation, cost and esthetics. The marginal fit may be acceptable or not when using any restorative system. Although the present study did not present significant differences, the original values from conventional and modified crowns were expected to be more approximate [22] as the fabrication process is quite similar. After obtained the metallic coping at the same technique, for the modified crown the gingival facial part of the metal coping is removed and replaced by ceramic for esthetic reasons. The marginal discrepancies showed to be highly technique sensitive from the tooth preparation to the crown fabrication. The number of steps involved in the process was an important element [18,19] because the probability of error increased with each additional step required [20]. The use of CAD-CAM technology was expected to provide marginal fit of better quality than the conventional systems by eliminating steps after finishing the tooth preparation [2,20,37] but other studies did not corroborate that statement [4,6,24].

The most widely used method for examination of the marginal area involve direct microscopic investigation but identifying reference points to measure may prove difficult. Although not the most accurate method, direct view measuring technique is cheaper and less time consuming than other techniques and reduce the chance of error accumulation that may results from multiple procedures and ultimately impact the accuracy of results [41]. Stereomicroscopes provided limited results from widely separated measuring points, hence calculated means usually demonstrate large standard deviations, and the results reported might be questionable [39]. There is no agreement in the literature concerning the number of measure sites necessary to evaluate marginal fit1 as this parameter seems critical because, within a distance of 300 µm, the marginal opening can fluctuate by 100 µm on the same specimen [43]. While using a larger sample size produced more consistent data with smaller

standard deviation [40] the smaller sample size can be compensated by larger number of measurement per sample [25]. Thus, in the current study the small number of specimens were partially compensate by the 16 measures obtained from each specimen, four from each tooth face. As the measures were recorded from the areas with the largest marginal gap the mean values probably represented the maximum misfit of the crowns, with values ranging from 36 to 196 μm (mean 74 to 102 μm). The X-ray microtomography was recommended as the only method capable of measuring the marginal gap *in vitro* [1].

Results from different studies should not be used to determine whether a method or material is better or not only. All data should be analyzed under the consideration of each study design [5] as even within the CAD/CAM system different software configuration may result in different marginal fit [4,23,24]. Selection of a system should not be based primarily on marginal accuracy, as the marginal adaptation of ceramic crowns from the various systems is generally clinically acceptable, but rather on a system's ability to produce the type of ceramics best adapted to existing clinical conditions and esthetic expectations [1].

Evaluating the marginal gap without crowns cementation was performed because the marginal gap was significantly increased after cementation [16].Thus, marginal gap larger than 100 μm combined with inappropriate handle of the cement may result in very poor marginal fit. The investigation using the stereomicroscope showed limitation in the gap measuring because of limitation to define the border from both the tooth and restoration. Although the present study used the larger areas of marginal gap a higher number of measures might led to more accurate results. Studies comparing the stereomicroscope and X-ray microtomography should be performed to reach more accurate results.

Conclusion

The selection of the crown restorative system should not be based on the marginal gap only as all systems presented similar results within the limit clinically acceptable.

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