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The Effect of Occlusal Surface Relief of Dies on Marginal Adaptation of Metal-Ceramic Casting Copings

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Abstract

Purpose: The purpose of this study was to evaluate the impact of occlusal relief of dies on internal adaptation of metal-ceramic casting copings.
Materials and Methods: Standardized preparations were made on 80 extracted third molar teeth. Impressions were made with poly(vinyl siloxane), and stone dies were prepared. Dies were covered with four layers of die spacer, covering the entire preparation together with the occlusal surface excluding the apical 0.5 mm of the preparation in group 1 (40 specimens), and covering the same area excluding the occlusal surface in group 2 (40 specimens). Copings were cast using nickel–chromium-based metal ceramic alloy and cemented using zinc phosphate cement. The specimens were sectioned along the long axis. Internal discrepancies were recorded with a 0.001-mm resolution stereoscope at 6 points: the middle of the occlusal surface (MO), middle of the lingual wall (ML), middle of the buccal wall (MB), middle of the buccal shoulder finish line (MSH), middle of the lingual chamfer finish line (MCH), and middle of the buccal bevel finish line (MBL). Student's *t*-test was used for statistical analysis. Significance level was set at $p < 0.05$.
Results: The marginal discrepancies of group 1 were higher than those of group 2. Significant differences in discrepancies were found on MO ($p < 0.0001$), MSH ($p = 0.012$), and MBL ($p = 0.035$). The bevel margin showed the least marginal discrepancy following occlusal surface of the die with no relief.
Conclusion: Leaving the occlusal part of the die uncovered with the die spacer improved the crown seating considerably in the occlusal surface as well as shoulder and bevel margins.

Cast restoration success demands perfect seating and marginal adaptation of the crown, which is affected by many factors during the fabrication process.[1] It has long been recognized that even if all variables are controlled carefully to ensure a precision fit, the restoration may not be seated completely due to insufficient space for the luting agent.[2,3] Incomplete seating of the restoration can cause difficulties such as occlusal interferences, loss of proximal contacts, marginal discrepancy, secondary caries, plaque accumulation, periodontal problems, rapid dissolution of cements, and tooth hypersensitivity.[4-7]

Fusayama et al reported more than 90 μm thickness of cement on the occlusal floors of full crowns. The thickness could be altered by applying some special means to relieve the heavy resistance of the cementing substance.[8] Several studies have shown that the seating of crowns is greatly improved, and the effects of luting agent hydraulic pressure can be overcome by internal relief.[1,3,4-6,8,9-12] Some methods of achieving internal relief include grinding the inside of the casting, internal carving of the wax pattern, etching with aqua regia, electrochemical milling, and venting. Die spacing has been the most popular method of achieving adequate internal relief.[5] The popularity of this technique has been attributed to its simplicity, convenience, and cost effectiveness. The use of die spacer reduces elevation of the cast restorations,[1,3,8,9-13] decreases seating time,[3] improves outflow of excess cement, and lowers seating forces.[3,11,13]

The amount of cement reaching the occlusal surface can be controlled and even totally prevented by applying cement and die spacer only to specific areas of the crown and preparation, respectively.[14] The emphasis in the literature on incomplete seating of crowns during cementation has focused on the thickness of die spacer,[1,5,12] or the surface area of axial walls of the die covered by the die spacer.[15] It seems more stress should be placed on the thickness of the die spacer on the occlusal surface as a means of solving the problem of incomplete seating, since the reported amounts of marginal discrepancy in castings are between 30 μm and 50 μm. On the other hand, the amount of incomplete seating of a cemented crown is equal to the thickness of the cement at the occlusal surface.[5] This amount is also similar to the ideal thickness of zinc phosphate cement, which is approximately 25 μm to 40 μm.[3]

To the best of our knowledge, there is no actual data on the effect of occlusal relief on marginal fitness of metal-ceramic casting copings in the literature. This study, therefore, was designed to evaluate the effect of occlusal surface relief of dies on the marginal adaptation of metal-ceramic casting copings. The null hypothesis was that the existence of any difference in marginal adaptation of copings was unlikely between the test groups.

Materials and methods

Eighty extracted third molar teeth were selected and stored in distilled water at 37°C until the experiment. The tooth roots were notched and stabilized in standardized acrylic tubes and embedded in orthophthalic unsaturated resin (Redefibra, São Paulo, Brazil). Standardized preparations for porcelain-fused-to-metal crowns were obtained using a milling machine (Sanches Blanes, Ribeirão Pires, Brazil) with water spray irrigation. The preparations had a 6 mm diameter at the occlusal surface, with a 12° taper and 4 mm height. A facial shoulder and bevel lingual chamfer were used as the gingival margin. The teeth were inspected for undercuts and correct taper angle on a profile projector (Type 32–12-11, Bausch and Lomb, Rochester, NY) with a goniometric table (Type 2, Nikon, Tokyo, Japan).[13] The teeth were aligned in a straight line with the axis perpendicular to the base. Two layers of pink baseplate wax (Truwax, Dentsply International Inc., York, PA) were adapted over each group as a spacer, and a custom resin tray was made with a VLC acrylic resin (Megatray, Dental Produkte Gmbh, Radeberg, Germany).

Stone dies (Vel-Mix, Kerr Mfg. Co., Romulus, MI) were prepared from poly(vinyl siloxane) impressions (Express, 3M ESPE Dental Products, St. Paul, MN), mixed mechanically in vacuum with a water:powder ratio of 0:22. After the stone had set for a minimum of 1 hour, the casts were recovered, and individual dies were numbered and divided into two groups randomly. After a minimum of 3 days, a Pico-Fit (Renfert, Hilzingen, Germany) die spacer kit was used to cover each group of dies using four alternating layers of silver and gold die spacer.[12]

The dies were grouped as follows: Group 1: die spacer covering the occlusal surface and the axial wall surface down to 0.5 mm short of the preparation margin; Group 2: die spacer covering the axial wall surface down to 0.5 mm short of the preparation margin without painting the occlusal surface. There was a 5-minute interval between each coat to ensure adequate drying. The estimated thickness was 20.84 μm to 39.12 μm.[16] Castings for metal ceramic copings were fabricated by a standardized method. Wax patterns were developed on the stone dies using type II blue inlay wax (Kerr Mfg. Co.). They were made with standardized dimensions (0.5 mm thick) using a wax gauge. An identifying number was marked in the wax pattern, ensuring that each cast coping would be returned to the proper tooth. The wax patterns were sprued and invested in a carbon-free, phosphate-bonded investment (Deguvest, Degussa, Hanau, Germany), prepared in an electrical evacuating and mixing unit (Multivac 4, Degussa). A standardized burn-out and preheat procedure was used. The crowns were cast in a nickel–chromium-based metal ceramic alloy (Porson4, Degussa) using a centrifugal casting machine (TiegelschleuderTS3, Degussa). Each casting was thoroughly cleaned of investment residue with a 50-μm aluminum oxide microetcher (Renfert). No other adjustment was made to improve restoration fit. The metal castings were seated on their respective teeth.

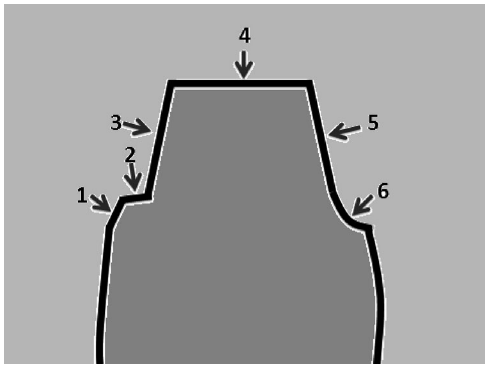

Figure 1 Vertical discrepancies at six points: middle of occlusal surface (MO), middle of lingual wall (ML), middle of buccal wall (MB), middle of buccal shoulder finish line (MSH), middle of lingual chamfer finish line (MCH), and middle of buccal bevel finish line (MBL).

For proper seating during cementation, a dimple was machined into the center of the occlusal surface of each casting with a No. 6 round carbide bur using a drill press. Each casting was filled with zinc phosphate cement (Harvard, Richter & Hoffmann, Dental-Gmbh, Berlin, Germany) with a ratio of 1.3 g powder to 0.5 ml liquid, seated with finger vibration and pressure, and immediately subjected to a 100 N load applied into the occlusal dimple for 10 minutes by a testing machine (Hounsfield Testing equipment, Surrey, UK). After cementation, the teeth were sectioned along the long axis with a low-speed, water-cooled, diamond saw (Labcut, Extec, Enfield, CT). The cut surface was finished under running water through 120, 240, 400, 600, and 4000 grit silicon carbide abrasive papers with a revolving polishing machine (Ecomet III, Buehler Ltd, Lake Bluff, IL).

After this procedure, the specimens were ultrasonically cleaned in water for 5 minutes. Finally, they were dried. Vertical discrepancies were measured at six points (Fig 1; middle of occlusal surface [MO], middle of lingual wall [ML], middle of buccal wall [MB], middle of buccal shoulder finish line [MSH], middle of lingual chamfer finish line [MCH], and middle of

Table 1 Mean and standard deviation of cement thickness (in μm) obtained from dies with (group 1) and without (group 2) die spacer on the occlusal surface at six measured points

	Group 1		Group 2		
Parameter	Mean	SD	Mean	SD	*p*
Mid-occlusal surface	208	71	117	47	0.0001*
Mid-buccal wall	80	33	68	37	0.112
Mid lingual wall	86	44	72	36	0.115
Mid buccal shoulder	106	47	81	38	0.012*
Mid- buccal bevel	50	27	39	18	0.035*
Mid-lingual chamfer	89	44	86	37	0.693

*Statistically significant ($p < 0.05$).

buccal bevel finish line [MBL]) after cementation for all specimens using a stereoscope (Stereoscopic Zoom Microscope; Nikon) with 20× magnification.

The measurements were repeated three times for each casting, and an average of the measurements was calculated. All measurements were taken by one operator. In addition to descriptive statistics (mean, standard deviation), Kolmogorov–Smirnov test was used for normal distribution evaluation, and independent Student's *t*-test was used to detect the differences between the two die spacer application groups. Statistical tests were performed with alpha levels equal to 0.05. SPSS v11.5 (SPSS Inc., Chicago, IL) was employed as the software for statistical analyses.

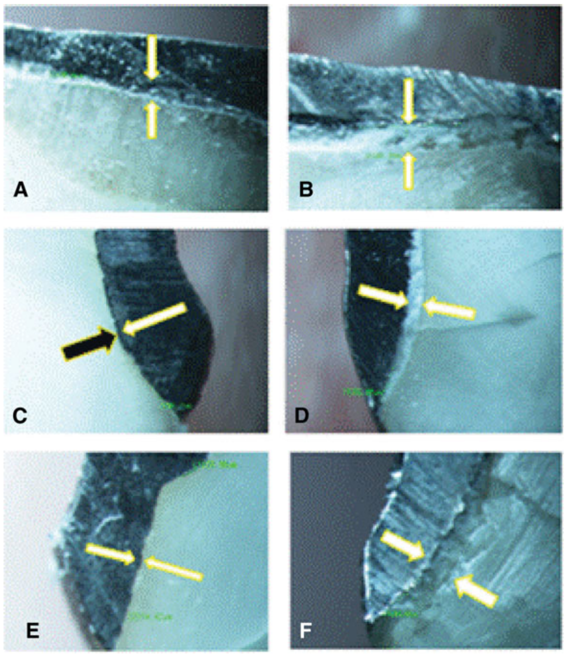

Figure 2 Stereoscope photomicrographs of the castings cemented with zinc phosphate (original magnification 30×) show the better marginal fit of group 2 (without occlusal relief of the die) compared to group 1 (with occlusal relief of the die). (A) Mid-occlusal surface in group 2; (B) Mid-occlusal surface in group 1; (C) Mid-chamfer in group 2; (D) Mid-chamfer in group 1; (E) Mid-bevel in group 2; (F) Mid- bevel group 1.

Results

The means and standard deviations of the cement film thickness at six measured points in the two groups tested with and without occlusal die spacer are shown in Table 1. Statistical analysis revealed significant differences between the two groups in three locations: MO ($p < 0.0001$), MSH ($p = 0.012$), and MBL ($p = 0.035$). Marginal discrepancies in group 1 were higher than those in group 2. No significant differences were observed between the two groups in the other locations: MB ($p = 0.112$), ML ($p = 0.115$), and MCH ($p = 0.693$). Stereoscope photomicrographs revealed better marginal fit in group 2 compared to group 1 in shoulder and bevel margin designs (Fig 2).

Discussion

The aim of this study was to compare the fit of castings made on dies with die spacer on axial walls down to 0.5 mm margin with or without occlusal relief. We evaluated the internal fit of the cemented castings by measuring the cement thickness after longitudinal sectioning at six points. The obtained data from cement thickness at the occlusal surface as well as at shoulder and bevel margins supported rejection of the null hypothesis, thus confirming statistically significant differences between groups. Data from the chamfer margin as well as lingual and buccal walls, however, failed to indicate any significant differences between groups. The results, therefore, suggest that leaving the occlusal part of the stone die uncovered with the die spacer improves the marginal fit of the casting at shoulder and bevel margins. This consideration in cast fabrication also decreases the cement thickness at the occlusal surfaces, according to the results. The amount of internal and marginal discrepancy in the present study was in the clinically acceptable range.[1,17-19]

The use of a standardized force and human teeth would be the ideal for simulating a clinical procedure,[20] and the design of the present study attempted to imitate a clinical situation in a similar manner. A great variety of descriptive terminology defining fit exists among investigators. Yet, in the course of the present study, the internal and marginal gap was defined as the vertical marginal discrepancy according to the terminology reported by Holmes et al.[21]

Marginal fit is known to be one of the most important criteria in the evaluation of clinical acceptability of crowns. Lack of adequate fit, a natural result of cement solubility or plaque retention, is potentially detrimental both to the tooth and supporting periodontal tissue health.

Grajower et al[13] stated that the possibility of obtaining "an optimum fit" of the casting is likely to exist in case relief space allows for the cement film thickness and roughness of the tooth and casting surfaces. The results of another study showed that uncovering the axial walls with the spacer impaired the crown fit considerably.[22] The average elevation of the crown without spacer was 653 μm, compared to 49 μm for the application of the spacer to the margin.

In this study, we applied the die spacer agent (Pico-Fit) in four alternate colored coats as recommended by the manufacturer, providing a 25-μm space. Die spacer was applied over the axial walls down to 0.5 mm short of the margins, leaving the occlusal part uncovered (group 2), examining the option of obtaining accurate marginal fit of the casting crown without application of die spacer on the occlusal surface. This technique of fabricating casting crowns proved to provide better marginal fit than when the occlusal surface of the die was fully covered with die spacer. In all specimens, a casting margin discrepancy existed at the finish line. Both in group 1 and group 2, the mean marginal gap at the chamfer margin was within the range of values reported by previous studies. These findings are in line with reported acceptable marginal gap widths (50–125 μm).[3,7–9,11,22,23] Furthermore, although no die spacer on the occlusal surface decreased marginal discrepancy in all evaluated areas, the decrease was significant on the mid-occlusal surface, mid-buccal shoulder finish line, and mid-buccal bevel finish line. The lowest marginal discrepancy was seen in the mid-buccal bevel finish line, while the highest decrease was observed in the mid-occlusal surface (Table 1). The latter findings are not in agreement with previous studies,[4,24] which may be due to the lack of the extra occlusal space and accumulation of cement on its surface.

Ishikiriama et al[25] found that cement painted on the inner walls of the crown promoted a better fit than the situation in which the crown was completely filled with cement. In a similar study,[14] Assif et al applied cement to various locations on the internal surface of the crown and to the prepared tooth. A 54-μm incomplete marginal seating was found when cement was placed on the margins of the crowns as compared to 106 μm when cement was applied to the apical half of the axial crown walls. By applying cement to the apical half of the axial walls of the prepared tooth, incomplete seating was 40 μm. It decreased to 10 μm when cement was applied only to the margin of the preparation.[5]

Although the flow pathway of the excess cement and the amount of incomplete marginal seating of the restoration has already been studied,[14] one issue left without being fully investigated has been the effect of die spacer application onto different parts of a die on seating of the crown. To date, no study has evaluated the effects of the occlusal relief of the die on the marginal adaptation of metal-ceramic restorations, and therefore, a comparison of the obtained results with the existing literature cannot be made at this time.

The marginal opening obtained for the castings made on dies without occlusal relief were substantially smaller than for the castings made on dies with occlusal relief (MSH2 $=$ 81.88 μm, MSH1 $=$ 106.67 μm, $p = 0.012$; MBL2 $=$ 39.31 μm, MBL1 $=$ 50.44 μm, $p = 0.035$; Fig 2). Since the amount of incomplete seating of a cemented crown is equal to the film thickness of the cement at the occlusal surface,[5] it seems that, regarding the present findings, the elimination of the occlusal relief of the die may reduce the possibility of cement accumulation at the occlusal surface and enhance the marginal adaptation; however, various kinds of cements have specific film thicknesses, and cement would occupy that much space, even if no space is allocated to it.[26]

Through the present methodology, we reached a significantly decreased seating discrepancy at the margin and occlusal surface via eliminating occlusal cement space. Preparing excessive space on the occlusal surface with die spacer for cement has been associated with increased cement accumulation on the occlusal surface, thus leading to increased seating discrepancy. Based on the Jorgensen filtration process,[27] on placing the crown containing the cement on the prepared tooth, cement accumulates on the occlusal surface. Cement must, therefore, travel a great distance and overcome frictional resistance to escape. At the same time, hydrodynamic pressure develops within the cement as the marginal opening prevents cement from escaping. Providing proper axial spacing and leaving occlusal surface uncovered with die spacer results in more rapid seating, which is due to the lack of extra space on the occlusal surface, and, therefore, seating would be completed before agglomerates can form. In other words, by controlling the amount of space for cement on the occlusal surface, we may well reduce the filtration process of Jorgensen. The film thickness of the cement layer has a direct impact on long-term clinical success, as it has been shown that an increase in zinc phosphate cement thickness decreases tensile bond strength of cement to cast metal.[28] Cement with a high film thickness is likely to fail to a great extent as a result of tensile strength. Fusayama[29] reported that film thickness of most kinds of cement was approximately 20 μm and stated that a thickness greater than 30 μm would contribute to solubility and failure of the restoration. Jorgensen[27] reported a 15 μm thickness under ideal conditions. Jorgensen and Esbensen[30] demonstrated that cement strength diminished approximately to one third as the thickness of cement increased from 20 μm to 140 μm. Therefore, the film thickness of cement should be maintained at an optimum level, and considering the results of the present study, this property may be obtained with no relief on the occlusal surface of the die.

Although the results were superior with the elimination of occlusal relief employed in this study, the effects of other variables, such as various types and different thicknesses of die spacer used at occluso-axial line angles, the type of the cement, the casting temperature, and the porcelain firing stages, on improving the adaptation of the castings were not investigated. Another limitation of the study was measurement of vertical marginal discrepancies alone, not quantifying the horizontal relationships. Therefore, further studies with higher sample sizes are suggested to evaluate the influence of other variables.

In clinical situations, it is laborious to precisely analyze the marginal adaptation of the fixed prosthesis to its respective abutment. It is essential to receive the prosthesis from the laboratory with minimum distortion. To optimize the cervical adaptation and to enhance the complete seating of crowns, it is compulsory to use die spacer 0.5 mm above the cervical line without occlusal relief during the laboratory procedure. The space obtained from no relief on the occlusal surface can be allocated to the thickness of the occlusal restoration, especially in lack of sufficient interocclusal distance. The reduced occlusal space of cement may also improve mechanical properties of the cement.

Conclusions

Considering the limitations of the present study, the following conclusions can be drawn:

(1) Marginal gap and cement thickness measurements on the shoulder, bevel, and occlusal surface were significantly

reduced with no relief of the occlusal surface of the die. The adaptation of metal-ceramic copings was improved accordingly.

(2) The absence of occlusal surface relief on dies did not significantly decrease discrepancies of the chamfer finish line and axial surfaces.

(3) The bevel margin with no relief of the die on the occlusal surface had the lowest marginal discrepancy.

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