Evaluating marginal fit and internal accuracy of various CAD-CAM copings- A SEM study

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Abstract

Background: *Marginal fit is critical for the success and longevity of a dental restoration. Zirconia crowns can be fabricated either chair-side, in a dental laboratory or in a milling center; each can give different marginal accuracy and internal fits. However, discussion of the marginal fit of zirconia crowns when different fabrication methods are compared is lacking in the literature.*

AIM: *This study was conducted to compare and evaluate the marginal accuracy and internal fit of base metal alloy copings fabricated through CAD metal laser sintering, zirconia copings fabricated by CAD/CAM technique and zirconia copings fabricated by copy milling using SEM (Scanning electron microscope).*

Material and method*: In vitro study was conducted in the to evaluate marginal accuracy and internal fit under scanning electron microscope of the zirconia copings fabricated using CAD/CAM and copy milling and metal copings fabricated using metal laser sintering using 36 Ivorine tooth (12 in each group) corresponding to mandibular 1st molar. Data were analyzed using the one-way ANOVA technique and Post hoc correction.*

Results*: CAD/CAM zirconia copings provide better marginal accuracy and better internal fit among the study group while comparing the internal fit of the metal copings fabricated by CAD metal laser sintering and zirconia copings fabricated by copy milling and CAD/CAM.*

Keywords*: CAD/CAM, Internal Fit, Marginal Accuracy, Zirconia*

1. Introduction

Metal ceramics have been the most widely used material for fabricating complete coverage crowns and fixed partial dentures. Esthetic problems with metal ceramics can be related to the metal coping, which affects the translucency of the crown by restricting the transmission of light and by increasing its reflectivity. To overcome this problem, several reinforced ceramic crown systems such as electroforming and composite alloys, which reduce the metal substructure to a thin foil were introduced to the market. A thinner metal coping allows for a thicker porcelain covering, increasing the esthetic appearance of the crown but still retaining some strengthening properties.1 Apart from mechanical properties like fracture resistance thermal conductivity and esthetics, another key factor that determines the long term clinical success of dental restoration are accurate marginal adaptation and internal fit.2 Marginal adaptation is one of the most important criteria for long term clinical success of dental restorations.3 The presence of marginal discrepancies expose the luting agent to the oral environment. The larger the marginal discrepancy and the subsequent exposure of the dental luting agent to oral fluids, the more rapid the rate of cement dissolution and microleakage[4] Marginal adaptation can be assessed by marginal discrepancy, horizontal marginal discrepancy, overextended margin, under extended margin, seating discrepancy, and absolute marginal discrepancy. The perpendicular measurement from the internal surface of the casting to the axial wall of the preparation is called the internal gap, and the same measurement at the margin is called the marginal gap.

The vertical marginal misfit measured parallel to the path of draw of the casting is called the vertical marginal discrepancy. The horizontal marginal misfit measured perpendicular to the path of draw of the casting is called the horizontal marginal discrepancy. There is also the possibility of overextended or under extended casting margins. An overextended margin is the perpendicular distance from the marginal gap to the casting margin. An under extended margin is the perpendicular distance from the marginal gap to the cavo surface angle of the tooth. The angular combination of the marginal gap and the extension error (overextension or under extension) is called the absolute marginal discrepancy.[5] The internal fit is evaluated by the gap between the intaglio surface of the restoration and the prepared tooth.

The purpose of this study is to evaluate and compare marginal accuracy and internal fit of zirconia copings and cast metal copings fabricated by CAD/CAM technique and ceramic coping fabricated by copy milling and CAD/CAM technique using scanning electron microscopy.

2. Material and Methods:

The in vitro study was conducted in the Department oof Prosthodontics, Crown and Bridge, Maulana Azad Institute of Dental Sciences, New Delhi to evaluate marginal accuracy and internal fit under scanning electron microscope of the zirconia copings fabricated using CAD/CAM and copy milling and metal copings fabricated using metal laser sintering using Ivorine tooth corresponding to mandibular first molar. The study comprised of 36 specimens divided into 3 groups. Each group was containing 12 samples.

Table1: Grouping of the samples

GROUP 1	GROUP 2	GROUP 3
Base metal copings fabricated by CAD Metal laser sintering	ZIRCONIA COPINGS	
	Copy milling technique	CAD/CAM technique

1. TOOTH PREPARATION USING DIAMOND POINTS:

Ivorine mandibular 1st molar (frasaco) was mounted on the frasaco typodont jaw. Standardized tooth preparation for porcelain veneer crown was prepared on typodont mandibular 1st molar using diamond points (SS white) . 1 mm chamfer margin of the tooth was prepared using TR 13(SS white). 2 mm of occlusal reduction on the buccal cusps and 1.5 mm occlusal reduction of the lingual cusps were done using flame shape diamond points. Functional cusp bevel was given on the buccal cusps of the teeth. Finishing of the buccal, lingual and promixal surface of the tooth preparation was done using finishing diamond points.

2. IMPRESSION MAKING PROCEDURE:

Stainless steel 307 was used to fabricate custom tray of the 2x2x2 cm in the dimension. 0.5 cm dimension handle was fabricated on the custom tray for easy handling of the tray. Clear self-cure acrylic resin was used to fabricate stent to hold the tooth preparation. Tray adhesive was applied in the tray. Duplicating silicone (Addition silicone) 1:1 was dispensed in the mixing apparatus and vacuum mixing done for 60 seconds. The duplicating silicone was poured in the impression tray on the vibrator to avoid incorporation of any air bubbles. The impression was allowed to set. Compressed air was used to remove tooth preparation from the impression to avoid tearing of impression.

3. FABRICATION OF DIES:

The silicone wetting agent was sprayed on the impression and allow to air dry. Type IV die stone (Bego) was dispensed using ratio of 100gm powder 20 ml of water. Die stone was hand mixed using

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rubber bowl and spatula for 1 min and vacuum mix for 30 seconds. The impression was poured on the vibrator to avoid incorporation of air in the die. The dies were allowed to set. The dies were removed from the impression using compressed air. A coat of Die hardener (DFS) was applied on each die & allowed them to air dry to prevent abrasion.

4. GROUPING OF THE SAMPLES:

A total of 36 samples were randomly divided into three groups based on the material and respective technique used to fabricate the copings

5. ABRICATION OF PATTERNS:

Die lubricant was applied on selected dies for copy milled procedure in order to fabricate resin patterns for easy removal without abrasion. Bead brush technique was used to fabricate the resin pattern (GC) on the die selected for copy milling procedure. A putty index using addition silicone of the resin pattern was made in order to standardize resin pattern of the other samples of same group. Resin patterns were fabricated on dies selected for copy milling procedure using the fabricated putty index.

6. COPY MILLING PROCEDURE:

Resin patterns were mounted on the scan holder and scan powder was sprayed on the patterns in order to scan the patterns. After scanning the partially sintered zirconia block were mounted on the holder for milling and milling at the speed of 5000 rpm was done. Copy milled pattern were cut from the block using straight fissure diamond point, taking care to prevent the distortion of the milled patterns . These patterns were placed in the furnace for sintering. The sintering was carried out starting from the temperature 30^{0}c up to 1100^{0}c at heating rate of 20^{0}c min holding at the 1100^{0}c for 2 hours and allowed to cool in the close furnace without any coolant.

7. CAD/CAM PROCEDURE FOR ZIRCONIA COPINGS:

Each die for CAD/CAM zirconia copings was placed in scanning apparatus for scanning . The dies were placed in way to allow all the margins of the dies to be scanned properly without undercut. Once the scanning were done for partially sintered zirconia copings the blocks were mounted on the milling machine for milling. After completion of milling the copings were cut from the block using straight fissure diamond points (taking care to prevent breakage of the copings) and placed in the furnace for sintering. The sintering was carried out starting from the temperature 300c up to 11000c at heating rate of 200c min holding at the 11000c for 2 hours and allowed to cool in the close furnace without any coolant.

8. CAD/CAM PROCEDURE FOR METAL LASER SINTERED COPINGS:

For MLS process the 3D CAD model was used to create STL file and transferred to the machine’s software. A technician worked with this 3D model to properly orient the geometry for “part building” and added “support structure” as appropriate. Once this "build file" was completed, the file was "sliced" into the layer thickness (of 20μm). The file was then downloaded to the DMLS machine allowing “the build” to begin. The DMLS machine uses the build chamber area. There was a material dispensing platform and a build platform along with a recoater blade used to move new powder over the build platform. The technology fuses metal powder into a solid part by melting it locally using the focused high laser beam. Parts were built up additively layer by layer, typically using layers 20 micro meters thick.

9. CEMENTION PROCEDURE:

After completion of fabrication of all the copings were collected and cleaned in distilled water. These samples were allowed to air dry. For zirconia copings sandblasting of the bonding surface of the copings were done. The monobond plus bonding agent was applied. The samples were allowed to react for 60 seconds and air dried. For DMLS copings metal primer was applied on the bonding surface and allowed to air dry for 60 seconds. The dual cure resin cement was applied on the bonding surface of the copings and placed on the dies. These dies were placed under alignment apparatus under the force of 750 gms for 10 mins. Light activation of the cement was done for 1-2 seconds. The gel "consistency" of the cement around the margins was removed with explorer. All the margins- buccal, lingual, mesial and distal were cured using curing light for 20 secs. All the samples were cemented in same manner and allowed to set further for 24 hours.

10. SECTIONING OF COPINGS:

After 24 hours of cementation each sample was mounted within dental stone. These mounted models were allowed to air dried for 24 hours in order to prevent any distortion of the samples. One set representing the six individual preparation was used for evaluation for marginal accuracy and internal fit were cut mid bucco-lingual and other six were cut mid mesio-distal directions using diamond disk on the alloy trimmer using intermediate irrigation to prevent over heating while cutting the samples. The samples were allowed to air dry in order to scan under electron microscope. The samples were cut further to create the 1 cm size that can be scanned under scanning electron microscope.

11. SEM (SCANNING ELECTRON MICROSCOPE) EVALUTION OF THE MARGINS AND INTERNAL ACCURACY:

Samples were mounted on a circular metallic sample holder available with SEMCF. The samples were fixed onto the sample holder rigidly enough so that they do not fall off easily while handling. Sticky carbon tape was use as adhesive to prevent the sample from displacing during scanning. The samples were examined under 300X magnification under electron microscope at following points.

1. X1, X2- Marginal discrepancy
2. X3, X5(at the cusp tip), X4(deepest point in the groove) Internal fit (occlusal surface)

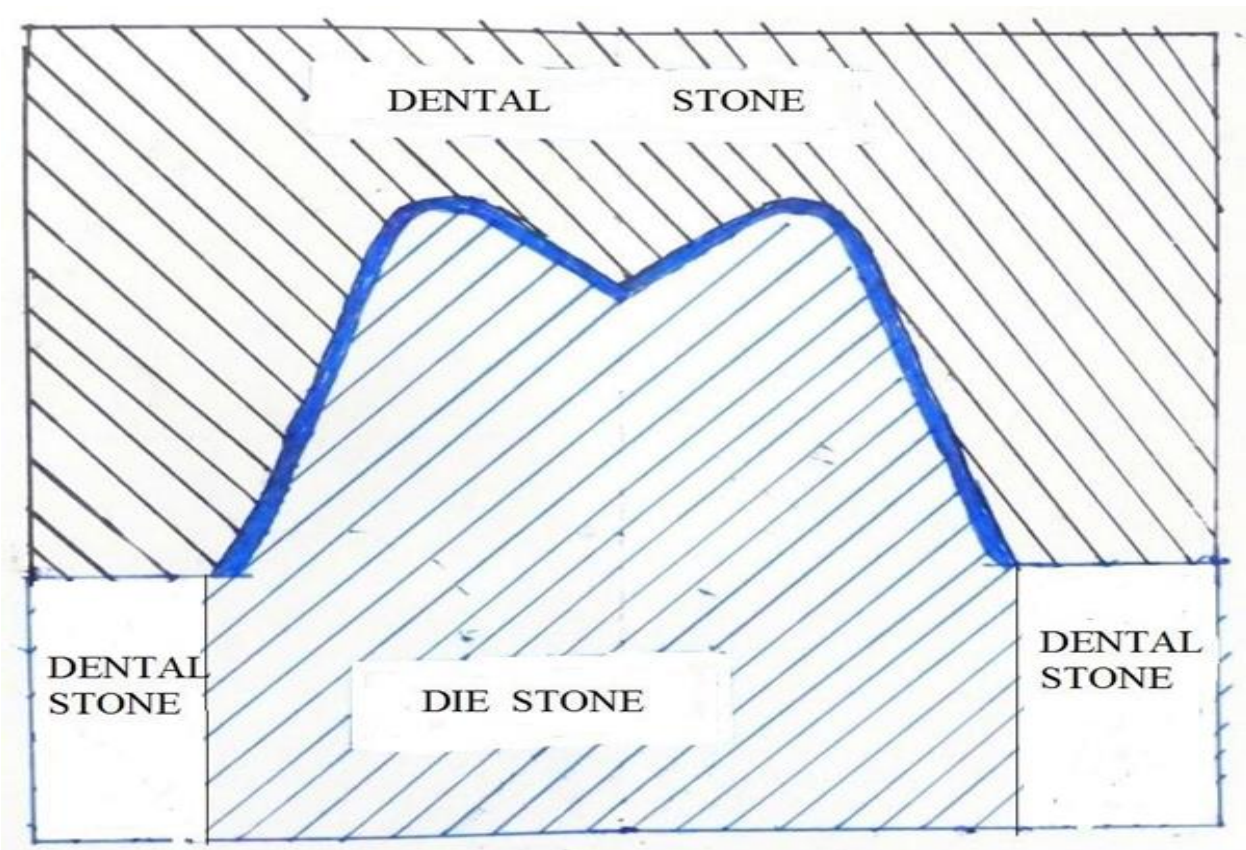
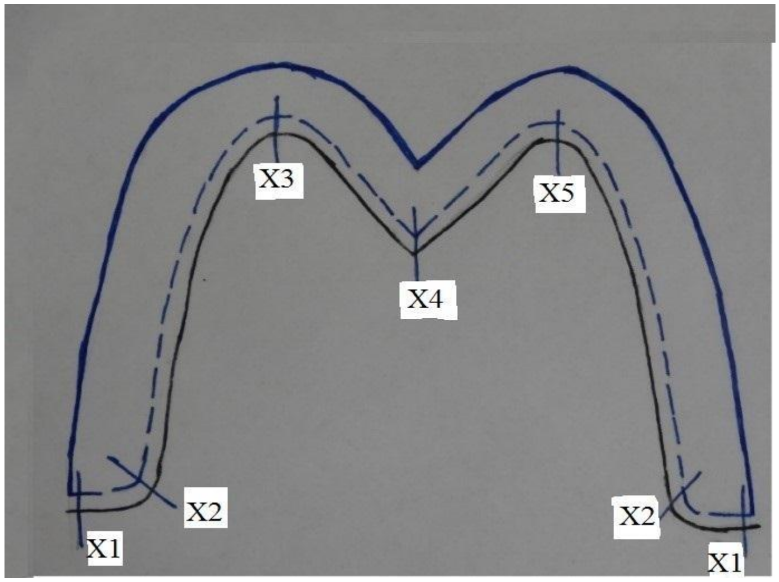


Figure 1: stabilization of cemented copings for sectioning



1. ***Figure 2: Schematic illustration of the measurement points: X1, X2=margin accuracy (crown margin),***

X3, X4, X5=internal fit X3, X5(cusp tip), X4 (Deepest point).

The parameters which were studied are as followed:

1. Marginal accuracy of the zirconia copings fabricated using CAD/CAM and copy milling and base metal copings fabricated by CAD metal laser sintering.
2. Internal fit of the zirconia copings fabricated using CAD/CAM and copy milling and base metal copings fabricated by CAD metal laser sintering

Marginal accuracy was calculated at four points i.e. at point X1 and X2 on both the sides respectively. Average marginal accuracy of the each group was then calculated which was used to determine the marginal accuracy. The statistical tests were applied to the data generated.Internal fit was evaluated at three points located at the cup tips the points are X3 and X5, X4 central fossa the point. Average of the internal fit of the each group was calculated and statistical tests were applied to the data generated.Mean and SD were calculated for descriptive analysis of each group.All the calculation were performed using the SPSS (version 17) for windows (SPSS inc., Chicago II, USA) . The mean value was evaluated by ANOVA-A test. For individual group comparison Post hoc Gamed-Howell test was performed. Level of significance was considered at 5 %(*P-value<0.05).

Tables

Table 1: The marginal gap (micro metres) at the points X1 and X2 shows marginal accuracy and the marginal gap (micrometres) at the points X3, X4 and X5 shows internal fit of CAD metal laser sintered copings, CAD/CAM zirconia copings and zirconia copings fabricated using copy milling

Group 1 **(Base metal copings fabricated using CAD metal laser sintering)**									
X1		X2		X3		X4		X5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
102.97	2.69	103.53	2.32	212.88	9.64	219.51	9.33	213.56	9.34
Group 2(Zirconia copings fabricated using CAD/CAM)									

X1		X2		X3		X4		X5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
79.74	5.81	80.23	5.89	181.31	4.32	184.56	4.54	180.07	4.04
Group 3(<u>Zirconia copings fabricated using copy milling)</u>									
X1		X2		X3		X4		X5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
113.09	4.87	113.75	4.23	188.68	6.55	195.06	10.44	189.33	7.13

Table 2 shows mean marginal accuracy and SD of each group respectively CAD metal laser sintering base metal copings, CAD/CAM and copy milling zirconia copings

		N	**Mean**	**SD**
Marginal accuracy	**Group1(CAD MLS)**	12	102.15	10.83
	Group 2(CAD/CAM)	12	80.03	5.83
	Group 3(Copy Milling)	12	113.42	4.55
	Total	36	94.50	15.81

Table 3 A: Comparison of marginal accuracy of the three different groups by one way ANOVA:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7031.748	2	3515.874	185.158	.000*
Within Groups	626.621	33	18.989		
Total	7658.368	35			

*. The mean difference is significant at the 0.05 level

Table 3 B: Comparison of marginal accuracy of the three different groups by Multiple correction Games Howell (TURKEYS POST HOC correction)

(I) material	(J) material	Mean Difference	Std. Error	Sig.*	95% Confidence Interval	
					Lower Bound	Upper Bound
CAD MLS	CAD/CAM	23.22320*	1.79356	.000	18.5242	27.9222
	Copy milling	-10.17097*	1.38137	.000	-13.7327	-6.6092
CAD/CAM	CAD MLS	-23.22320*	1.79356	.000	-27.9222	-18.5242
	Copy milling	-33.39418*	2.09027	.000	-38.6786	-28.1097
Copy milling	CAD MLS	10.17097*	1.38137	.000	6.6092	13.7327
	Copy milling	33.39418*	2.09027	.000	28.1097	38.6786

Table 4: mean marginal accuracy and SD of each group respectively CAD metal laser sintering base metal copings, CAD/CAM and copy milling zirconia coping

		N	MEAN	SD
Internal Fit	**Laser**	12	215.31	9.78
	CAD/CAM	12	181.98	4.72
	Copy Mill	12	191.05	8.60
	Total	36	196.11	16.20

Table 5: Comparison of internal fit of the three different groups:

A: One way ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6695.851	2	3347.926	73.948	.000
Within Groups	1222.394	27	45.274		
Total	7918.245	29			

*. The mean difference is significant at the 0.05 level

B: Multiple corrections Games Howell (TURKEYS POST HOC correction)

(I) material	(J) material	Mean Difference (I-J)	Std. Error	Sig.*	95% Confidence Interval	
					Lower Bound	Upper Bound
MLS	CAD/CAM	34.58961*	3.00863	.000	26.5484	42.6308
	Copy milling	24.24708*	3.76326	.000	14.5362	33.9580
CAD/CAM	MLS	-34.58961*	3.00863	.000	-42.6308	-26.5484
	Copy milling	-10.34253*	2.75517	.010	-17.9253	-2.7598
Copy milling	MLS	-24.24708*	3.76326	.000	-33.9580	-14.5362
	CAD/CAM	10.34253*	2.75517	.010	2.7598	17.9253

3. Results:

In group 1, mean marginal gap and SD (micrometres) at each point for CAD metal laser sintering base metal copings as follow. For marginal accuracy X1=102.97±2.69, X2=103.53 ± 2.32 and internal fit X3=212.88 ± 9.64, X4=219.51 ± 9.33 and X5=213.56 ± 9.34. (Table 1) In group 2, mean marginal gap and SD (micrometres) at each point for CAD/CAM zirconia copings as follow. Marginal accuracy X1=79.74±5.81, X2=80.23 ± 5.89 and internal fit X3=181.31 ± 4.32, X4=184.56 ± 4.54 and X5=180.07 ± 4.04 were recorded. (Table 1)In group 3, Mean marginal gap and SD (micrometres) at each point for copy milling zirconia copings as follow. For marginal accuracy X1=113.09 ± 4.87, X2= 113.75 ± 4.23 and internal fit X3=188.68 ± 6.55, X4=195.06 ± 10.44 and X5=189.33 ± 7.13. **(Table 1)**

Mean marginal gap and SD (micrometres) for marginal accuracy of CAD metal laser sintered base metal copings 102.15 ± 10.83, CAD/CAM zirconia copings 80.03 ± 5.83, and copy milling zirconia copings 113.42 ± 4.55. **(Table 2)** For marginal accuracy One way ANOVA shows significant difference between the group with df 2 and F value 185.158($p < 0.05$). **(Table 3A)** Post hoc (Games-howell) test shows there were significant difference between CAD metal laser sintered base metal copings and CAD/CAM and Copy milling zirconia copings with p- value 0.00. CAD/CAM zirconia copings show more marginal accuracy followed by CAD metal laser sintering base metal copings and Copy milling zirconia copings. **(Table 3B)** Mean marginal gap and SD (micrometres) for internal fit of CAD metal laser sintered base metal copings 215.31 ± 9.78, CAD/CAM zirconia copings 181.98 ± 4.72, and copy milling zirconia copings 191.11 ± 8.60. **(Table 4)** For internal fit One way ANOVA shows significant difference between the group with df 2 and F value 73.948 ($p < 0.05$) **(Table 5A)** Post hoc (Game-howell) test shows there is significant difference between CAD metal laser sintered copings and CAD/CAM and Copy milling zirconia copings with p- value 0.00. Internal fit of CAD/CAM zirconia copings were better followed by Copy milling zirconia and CAD metal laser sintered copings. **(Table 5B)**

4. Discussion:

Marginal accuracy and internal fit are important parameters that determine the clinical longevity and success of restorations, including Fixed Dental Prosthesis. Despite numerous technological advances, obtaining an effective, long lasting marginal seal at the tooth restoration interface is still a great challenge. The increased marginal discrepancy of the crown favours an increased rate of the cement dissolution and micro leakage. Poor marginal adaptation of the restoration increase plaque accumulation and change in sub gingival micro flora, contributing to the onset of periodontal disease.[6]

Cobalt-chromium alloy (Co-Cr) is often described as a biocompatible material, and because of the high cost of gold or the allergic reactions associated with nickel-chromium, it is widely used to fabricate metal frameworks.[7,8]Computer aided design and computer-aided manufacturing (CAD/CAM) milling and direct metal laser sintering (DMLS) manufacturing systems have recently been introduced for fabricating metal frameworks for metal ceramic crowns to overcome the limitation of the casting method. In the CAD/CAM milling system, a digital production pre shape is generated via computer; then a reconstruction is manufactured in the CAM section by using CAD data.[6] during the milling procedure the virtual pre shape serves as a pattern for milling a reconstruction from a solid Co-Cr blank. DMLS, which is an additive metal fabrication technology uses a high-temperature laser beam to selectively heat a substructure metal powder based on the CAD data with the framework design. A thin layer of the beamed area becomes fused, and the metal framework is completed by laminating these thin layers. [6,9]Porcelain fused to metal restorations are commonly used in fixed prosthodontics because of fair casting accuracy, the high strength properties of the metal, and their wide acceptance. Over the last 3 decades, interest in more esthetically pleasing and metal-free restorations have increased the demand for all-ceramic restorations and several systems are currently available. Based on the excellent physical properties, zirconia has been advocated as framework material for all ceramic FDPs.[3]

A high degree of variation in marginal fit has been reported for different all-ceramic crown systems. The marginal fit of a specific all-ceramic crown system has been evaluated in various in vitro studies and also showed a high variation ranging from between 28 µm and 160 µm. Since the cementation is likely to increase the marginal discrepancies of crown systems an in vivo study evaluating marginal discrepancies might put the mentioned results into clinical perspective. Previous in vivo studies have investigated either all ceramic crowns or inlay restorations, showing a high variation from 73 µm to 145 µm, with maximal values up to 500 µm. There is lack of literature comparing the clinical marginal fit of all ceramic FDPs to metal ceramic crowns.[10] The present in vitro study comparing the marginal fit of zirconia copings fabricated through the CAD/CAM and copy milling and base metal copings fabricated through CAD metal laser sintering. The present study was in vitro cross sectional study comparing the marginal accuracy and internal fit of the zirconia copings and metal copings fabricated using computerized systems. The presented study is an in vitro study comparing marginal accuracy and internal fit of base metal copings fabricated by CAD Metal laser sintering, zirconia copings fabricated by CAD/CAM and copy milling technique.

In the present study marginal accuracy was better for CAD/CAM zirconia copings than CAD metal laser sintering base metal copings and copy milling zirconia copings. Mean marginal accuracy for CAD metal laser sintered base metal copings was 102.15±10.83, for CAD/CAM zirconia copings 80.03±5.83 and for Copy milling zirconia copings 113.42±4.55. One way ANOVA shows no significant difference among the group measured for marginal accuracy.

Similar results were found in the study conducted by Tamac et al[11]to compare the clinical marginal and internal adaptation of metal ceramic crowns fabricated with 3 different techniques: computer-aided design and computer-aided manufacturing (CAD/CAM) milling (CCM), direct metal laser sintering (DMLS), and traditional casting (TC). The mean marginal gap values were 86.64 mm for CCM, 96.23 mm for DMLS, and 75.92 mm for TC. One-way ANOVA revealed no statistically significant differences among the groups for measurements at the marginal gap. Kartin Q[1] conducted a study and compared marginal fit and internal accuracy of metal ceramic crown fabricated through metal laser sintering and found that No statistically significant differences between the two alloys were found at any time. The mean marginal discrepancies ranged from 74 to 99µm for both alloys. The internal gaps ranged from 250 to 350µm.Gonzalo E[12] compared the marginal accuracy of CAD/CAM and metal ceramic crowns under scanning electron microscope and 1000 X comparing the groups (1) metal-ceramic, (2) Procera Bridge Zirconia, (3) Lava All Ceramic System, and (4) Vita In-Ceram YZ 2000 and it was found that accuracy of fit achieved by the four groups analysed was within the range of clinical acceptance.The results for internal fit of the Procera system was lower (26±19μm) than Lava system (76±36μm). Three way ANOVA showed significant differences (P< 0.001) in marginal adaptation between both ceramic groups, but no significant difference were observed for marginal fit between abutments. Procera Bridge Zirconia to have the best marginal fit using both measurement methods. The metal ceramic crown had least accuracy in the study group.Wettstein F, Bindl A[13] in their studies found that marginal accuracy was higher than metal ceramic crowns fabricated using lost wax technique. This increase in the measurements for Zirconia frameworks may be attributed to the CAM system (Copy milling) that is employed in this study. Other reason for increase in the measurements for Zirconia frameworks may be attributed to the use of Pre sintered blocks in this study. Similar result was found in the study conducted by Ragish KM [3]. The study stated that the mean marginal accuracy (in micrometers) for Ni-Cr crowns before and after veneering was 124.44±19.26 and 162.03±54.07 respectively while for copy milled zirconia crowns (before and after veneering) it was 191.09±16.91 and 242.54±91.67 respectively. Mean internal fit for Ni-Cr crowns before and after veneering (in micrometers) was 204.48±46.99 and 205.24±51.76 respectively, while for copy milled crowns it was 274.80±20.35 and 238.34±55.67 (before and after veneering) respectively. The study suggested that copy milling zirconia crown had higher marginal and internal discrepancy than conventional lost wax technique found contradictory to finding in presented study.

5. Summary and Conclusion

CAD/CAM zirconia copings provide better marginal accuracy and better internal fit among the study group while comparing the internal fit of the metal copings fabricated by CAD metal laser sintering and zirconia copings fabricated by copy milling and CAD/CAM. The mean discrepancy of marginal accuracy and internal fit of the copings fabricated from all the groups were within the clinically accepted value.

To overcome the limitation of the study conduct a similar study with a larger sample size to validate effectiveness of marginal accuracy and internal fit of the zirconia and metal copings with minimum thickness of the cement, standard method to investigate marginal accuracy and internal fit, chosen for the study should be taken in to the study. It is also recommended to conduct the similar study before and after ceramic firing and compare marginal accuracy and internal fit before and after cementation to evaluate accuracy of fabrication technique.

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