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Evaluation and comparison of the marginal fit and axial wall adaptability of cast- metal ceramic alloy copings, direct metal laser sintered copings and zirconia copings- An Invitro study

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Abstract

Statement of the problem: The art and science of fixed prosthodontics is predicted on accomplishing precise and clinically accurate operative techniques based on sound biological and mechanical principles. Success of a fixed restoration depends to a large extent on the fit between the restoration and the prepared tooth surface. Lack of adequate fit is potentially detrimental to both the tooth and the supporting periodontal tissues. Many recent inventions have done to overcome this problem and create proper adaptation between crown and tooth structure.

Purpose: To evaluate and compare the marginal fit and axial wall adaptation of cast metal ceramic alloy copings made by conventional lost wax technique, direct metal laser sintered copings (DMLS) and zirconia copings.

Materials and Methods: A master die made of aluminium alloy was fabricated and duplicated with polyvinyl siloxane and working models were made with type IV die stone. Twenty copings of conventional metal ceramic copings, twenty DMLS copings, twenty zirconia copings were fabricated and cemented to working models. Four markings were made on finish margin at 0º,90º,180º,360º. The marginal fit was evaluated using stereomicroscope. Later the copings were sectioned into two halves using carborundum disc and then seven markings were placed three on occlusal surface, two on axial surfaces of both sides. Stereomicroscopic analysis was done and axial wall adaptation was determined.

Results: The obtained marginal fit values at four different points and axial adaptation values at seven different points were sent to statistical analysis. Based on the mean and standard deviations and analysis using ANOVA, statistically significant difference was noticed and the marginal fit and axial wall adaptation is better for conventional metal ceramic copings.

Conclusion: In this study based on the results obtained it was concluded that the marginal fit and axial wall adaptation was comparatively superior to conventional metal ceramic copings followed by zirconia copings and then the DMLS copings.

Clinical implications: The main intention of the study is to evaluate the copings having better marginal fit and adaptation so that they can be preferred more in the clinical practice. Good marginal fit and adaptation leads to long run of the prosthesis which gives a way to the patient to develop trust on the Prosthodontist.

Keywords: Copings, Zirconia, DMLS, Metal Ceramic, Marginal fit, axial wall adaptability.

Introduction

Fixed prosthesis in dentistry is long-lasting and predictable dental application in which patient's acceptance is more because of its comfort, convenience, function and aesthetics[1]. Earlier the fixed bridges were connected to adjacent teeth with gold and copper wires, bands etc.

Later in 1970 with the advent of lost wax technique by Taggart; which revolutionized the future of dentistry. Later the use of Ni based alloys became very popular which contains Beryllium in small amounts. Be containing alloys casts better and also form stronger bond between porcelain and metal than those not containing Beryllium[2].

But because of the potential health hazard of nickel and Beryllium later some Co-Cr alloys were used. But based on castability, solderability and bond strength Ni-Cr alloys were most widely used compared to other alloys[2].

Because of revolutionary changes in aesthetic dentistry the evolution of dental ceramics took place. As ceramics are brittle in nature, they need a certain back up for reducing the brittleness. Several conventional metal copings were used over which the ceramic layering was done and later DMLS copings came into existence over which the ceramic layering was done to reduce the brittleness.

The errors that occur at each stage such as impression making, die fabrication, wax pattern etc. which are technique sensitive and laborious tasks in conventional lost wax technique.

In order to overcome such problems, the recently developed direct metal laser sintering (DMLS) technology and CAD/CAM technology came into existence[3]. While traditional lost wax casting methods may waste metal during spruing and other procedures, the DMLS technology could eliminate metal waste by firing the required amount. The DMLS technology has several advantages, including fabricating complicated structures quickly, and removing procedures such as wax pattern fabrication, investing, burnout, and casting. While an excellent marginal fit is necessary for a successful dental prosthesis, there is limited information on the marginal fit of fixed dental prostheses created with DMLS technology[3].

Based on the esthetic requirements of present generation, the advancement of computer aided design and manufacturing technology (CAD-CAM) grew very much faster and has brought remarkable changes in dental laboratory sector. The preformed commercially available material blocks were used for milling to produce higher or more consistent quality restorations, and also reduces production cost and time.

A successful fixed dental prosthesis relies mostly on the marginal fit (FDP). The marginal fit is affected by the axial wall adaption, which impacts the seating of a prosthesis, making it equally significant. Incomplete marginal fit causes cement breakdown, secondary caries development, unfavourable pulpal reactions, and perio dontal in flammation[5]. Perceptive tooth preparation, correct imprints, precision castings with detailed finishing, and cementation methods all contribute to the marginal fit and axial wall adaptability of castings. So in order to overcome the errors and difficulties in conventional techniques some of the new technologies came intoexistence.

In this study I want to know by comparing the marginal fit and axial wall adaptability which are the keys for success of fixed restorations were better for either conventional cast metal copings or recently developed DMLS copings or CAD/CAM milled Zirconiacopings.

Materials and methods

Fabrication of master model

A master model with a die and two guiding pins was fabricated using aluminium alloy. The diameter of the entire model is about 60mm, and die is placed precisely at the canter, and two guiding pins are placed 10mm away from the die on both sides. The occlusal diameter of the die is about 6mm, and the height of about 5mm from the finish line. The guiding pins are fabricated to place the counter die precisely in the same position. The counter die should be fabricated so that the master die can easily pass through it, and space should be 1mm more significant than that of the die to provide space for the wax pattern.

Fabrication of working models

Impression of the master die was made using polyvinyl silicone impression material in a custom-made tray. A working model was made using die stone. The working models were measured mesiodistally, occluso-gingivally, and buccolingual using a metal gauge for standardization. Working models with standardized measurements were selected.

Preparation of cast metal-ceramic alloy copings

These copings were prepared by the lost-wax technique in a centrifugal induction casting machine. A single layer of die hardener and four coats of die spacer were applied on the prepared surface of working models. Wax patterns for copings were made using inlay wax. The thickness is standardized and measured using a wax gauge. Sprue is attached to the wax pattern, invested, and cast in the casting machine. The finished copings were placed on the working models without the spacer. The new working models were also standardized by measuring the occluso-gingival, mesiodistal, and buccolingual width.

Preparation of direct metal laser sintered copings

Copings were made in the DMLS machine, where the scanner read working models by an experienced dental technician. DMLS technology fuses metal powder into a solid by melting it locally using the focused laser beam and was built up additively layer by layer. For fabrication of DMLS copings, Medit T300 scanning machine was used with Exocad software for scanning, and Bego material was used for milling.

Preparation of the Zirconia copings

The copings are scanned. The scanned images are transferred to computer software (CAD). Then the crowns were designed using software and then milled by a milling machine assisted by software. A single block of zirconia was used for milling a coping. Thus zirconia copings were obtained. In the fabrication of zirconia copings, the Medit T310 scanning machine was used with Exocad software, and for milling, hypo dent software was used. Vita in-ceram block was used for fabricating the zirconia copings.

Measurement of marginal fit

The copings obtained from three groups were taken. Four markings were marked at the most apical portion of copings that is at the margins of die. The markings were placed at mid buccal, mid mesial, mid lingual, mid distal. The marginal fit was measured by using a stereomicroscope at four different places, as marked earlier. The software used in the present study was image viewer. The average of the values was calculated and taken as the marginal fit of each coping.

Measurement of axial wall adaptability

For measuring the axial wall adaptability, the copings were cut into two sections, and then seven markings were placed; two on each axial wall and three on the occlusal surface. Using the stereomicroscope, the thickness of cement is measured at seven different places, and the average was taken as axial wall adaptability.

The results were collected and send for statistical analysis.

Results

When compared between Conventionally cast metal ceramic copings, DMLS copings and Zirconia copings for marginal fit, better fit was obtained for metal ceramic copings, followed by Zirconia and highest marginal discrepancies wereobserved for DMLS copings.

The data was collected statistically analysed with ANOVA and based on mean and standard deviation s obtained the statistically significant differences between three groups were obtained i,e $P < 0.05$.

Discussion

The clinical success of crowns and fixed dental prostheses is determined by their marginal fit and axial wall adaptation[1]. Because of the intraoral deterioration of cements, which invariably causes loss of marginal seal and encourages plaque and food debris retention, leads to inadequate fit of crowns which might be hazardous both for the abutment tooth and crown also[1].

In the present study, the comparison of the marginal fit and axial wall adaptability of the metal copings fabricated by conventional lost wax technique and by digital methods like laser sintering for DMLS copings and CAD-CAM for Zirconia copings.

Coping strategies from three different groups were gathered and analyzed. Type I GIC was used to cement the copings of three separate groups to the working models. With both rough and smooth tooth preparations, glass ionomer cement gave the best fit. The marginal fit of the restoration can be influenced by flow characteristics and film thickness. G.I.C. comes in various film thicknesses ranging from 7.24µm to

20.5µm[18]. According to International Organization of Standardization and American Dental Association regulations, the coating thickness of zinc phosphate cement should not exceed 25µm. In comparison, White and Yu recorded a film thickness of 28µm. The film thickness of resin cement has been studied in several investigations and has been found to be between 31 and 45µm[18].

So Glass Ionomer Cement was chosen because of its low viscosity, low film thickness and high plastic deformation in compression[21]. Even though the samples were cemented under constant seated stress, small changes in the cement layers' thickness could have influenced the misfit values. Manual mixing was used to imitatethe clinical conditions[22].

The finger pressure was applied to the coping after cementation until it was set. But some studies revealed that finger pressure does not yield good result as it is not standardized. According to Esra Koc's research, the cementation process had no substantial impact on marginal gaps[23]. However, according to Pablo Gomez Cogolludo's research, the cementing procedure often increases the marginal discrepancy[24].

According to Assif et al., the mean marginal gap is closer to 140µm, but Hung et al.[25] found the same parameter about 50-75µm. The average marginal gap of 200m, according to Gulker, can be tolerated[26]. According to McLean and Von Fraunhofer, a marginal cleft of 120µm can be clinically accepted[27].

In the present study, the mean marginal gap obtained was 76.5µm, 84.125µm, 79.025µm for metal, DMLS, and zirconia copings. The axial gaps acquired were 29.4µm,36.9µm,31.2µm for conventional metal copings, DMLS copings, and Zirconia copings, respectively. The values obtained were within the limits of various studies. In the present study i,e. compared to the Metal, DMLS, and zirconia copings, the marginal fit is better for conventional metal copings.

The results of this study, when comparing conventional cast metal copings to DMLS copings, were similar to those of Ucar et al, who found that the marginal gaps in metal and DMLS copings were insignificant. Still, the internal gap measured by the weight of filled light body silicone was significantly more significant in the DMLS system when compared to the conventional method.

Compared to conventional metal copings, the results of this investigation were likewise comparable with those of Kim et al., who found that the groups subjected to laser sintering have greater significant values for both marginal fits and axial wall discrepancies. The metal-ceramic crown gap values in the S.L.S. group are much higher than in the traditional casting group. When ceramic build-up was done over the metal cores in both conventional and laser sintering[30], however, the gap values considerably increased.

In another study, Kim et al. found that the marginal fit of DMLS crowns was much worse than the conventional technique. They eventually concluded that the DMLS system needs to be improved further for clinical use.

The findings of this investigation contradict those of Ortorp et al., who found that DMLS copings fit better than standard cast copings[31]. Moreover, in this study, the results may be varied because the master model was made with epoxy resin, and also they conducted a survey of the three-unit fixed prosthesis

It also contradicts the findings of Bhushan Gaikwad et al., who found that DMLS copings have a better marginal fit and consistent axial wall flexibility than copingsmade using the traditional lost wax technique.[1]

When comparing metal copings to zirconia copings, the results of this study were similar to those of Freire et al., who reported that typical metal copings had a smaller marginal gap than monolithic zirconia[28]. Similarly, Tamac et al. conducted a study and found that copings manufactured using the traditional casting approach had a smaller internal gap than those made using the CAD/CAM milling technique[29].

This could be due to human mistakes or the employment of different technologies in milling or scanning the specimens, resulting in various disparities.

However, the findings of this study contradicted those of Nayana Paul et al., who found that CAD/CAM crowns had superior fit accuracy than metal-ceramic crowns manufactured using the traditional lost wax approach. There are large variances in the mean marginal and internal gaps[3]. The occlusal gap was greater than the marginal and axial gaps for both crowns.

The marginal discrepancies for zirconia restorations were much more minor than those for metal-ceramic repairs in the study by Esther Gonalzo et al. The obtained vertical marginal adaption values were all within clinically acceptable limits[12]. The various discrepancies may be due to the manual errors in fabricating metal-ceramic groups. The scanning ability may also record precise details in zirconia, which aids in a better fit.

According to Esra Koc et al.'s research, the marginal gaps are much more significant for traditional metal copings and significantly lower for Cercon restorations[23].

However, more research is needed because there are substantial changes in metal and Cercon gaps, but not in the remainder of the zirconia restorations.

According to Jong-Kyoung Park's research, the average marginal gaps achieved for casting, computer-assisted milling, and DMLS were 36.96m, 63.21m, and 70.98m, respectively[32]. As a result, the mean marginal gaps for DMLS were higher than for conventionally cast metal copings and zirconia copings, which was consistent with the current investigation. It also shows that metal copings have a superior marginal fit than DMLS and zirconia copings.

Depending on the expertise of the dental laboratory technician[39], direct human intervention in the crown fabrication process could play a role. Another critical factor was the number of steps in the procedure because the probability of error rose with each additional step.By specifying that fine-grained cement should produce substantially superior results[33], Jorgensen and Petersen demonstrated that cementation could severely compromise marginal adaptation.

The measurement methods were another aspect that could substantially impact the results in diverse research. First and foremost, microscopic examination is the most extensively utilized method of measuring. Various microscopes were employed, including a stereomicroscope, a metallurgical microscope, and a scanning electron microscope. The findings may vary depending on the type of microscope utilized and the software used by each microscope. It could result in projection errors[34].Laser videography was another approach used to measure axial wall adaptability but not marginal accuracy because it could not record specific reference locations for determining the marginal fit.

The minimal disagreement was also measured using profilometry however this resulted in incorrect interpretations[39]. Another measurement technique is x-ray microtomography, a new and non-destructive technology that provides 2D and 3D imaging of the space between the implant and the die, allowing for a large number of measurement sites and easy recognition of crucial distances[39].

In vivo investigations have significant drawbacks, such as more complex dental preparation due to accessibility and the possibility of eyesight impairment[35]. The finish line placement, periodontal health, sulcus bleeding, saliva flow rate, and patient compliance can all affect the quality of the imprint. In a well-designed in vitro experiment[36], all of these factors can be adequately recreated.

The number of measurement sites used in a study might also affect the outcomes. To keep the numerical variance to 5µm, Groten et al. proposed taking 50 measurements of the marginal fit. Gassino et al. contended that Groten et al.'s findings were incorrect and that 18 observation points were required to properly evaluate experimental crowns.[37]

Few studies have measured marginal discrepancies during the coping stage, and even fewer have done so at the crown stage, where thickness plays a role in discrepancy values. However, comparing single-layer crowns to multi-layered crowns necessitates assessing fit at the crown stage[11].The rotary device utilized for tooth preparations had a noticeable influence on the axial wall surface features of complete crown preparations, according to Mohammedd F. Ayad's study[18].

The Nayana Paul et al. investigation findings were similar to those of the current study, revealing that the mean marginal and internal gaps differed significantly within a measured tooth. For both groups, the occlusal gap was larger than the marginal and axial gaps[3].According to Harsh Kasab Wala et al [38], DMLS copings have more marginal differences at proximal surfaces than at buccal and lingual edges, which could be owing to the scanner's failure to capture the data.

Thus various factors play a role in obtaining better marginal fit and adaptability. Based on various reasons and methods, the marginal fit and axial wall adaptability were comparatively better for metal copings, followed by zirconia copings and DMLS copings.

Limitations

1. The present study was done invitro and cannot represent the oral cavity as in anin-vivo study.
2. Though the impressions are made for every model, the accuracy may varybecause of shrinkage etc.…
3. The Stereomicroscope used was in 40x magnification, and there are many other advanced measuring devices with better magnification.
4. The number of samples taken was comparatively minimum, and more samples can be taken for better accurate results.
5. The finger pressure is used in the present study, which may vary while setting thecement.

Scope of the study

1. Further research can be done to evaluate marginal fit and axial wall adaptability for obtaining accurate results using more precise measuring devices.
2. In vivo studies have to be done to correlate with the results obtained from in-vitrostudies

Conclusion

Within the limitations of the study following conclusions were drawn.

1. The marginal fit of conventional metal copings was far superior to DMLScopings.

2. The marginal fit of conventional metal copings was almost similar to that of zirconia copings, but comparatively, metal copings were superior.

3. The axial wall adaptability of conventional metal copings was excellent toDMLS copings.

4. The axial wall adaptability of metal and zirconia copings was almost similar, but metal copings were somewhat superior to Zirconia copings.

5. The occlusal gaps obtained for all the three copings were more whencompared to axial gaps.

6. Again, the occlusal gaps were more for DMLS copings, followed by zirconia copings and then metal copings

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Tables

Comparison of the marginal fit of Metal ceramic copings, DMLS copings and Zirconia copings

		Sum of Squares	df	Mean Square	F	Sig.
buccal	Between Groups	4671.499	2	2335.749	4.747	0.012
	Within Groups	28045.941	57	492.034		
	Total	32717.440	59			
lingual	Between Groups	330.460	2	165.230	0.449	0.640
	Within Groups	20963.280	57	367.777		
	Total	21293.739	59			
mesial	Between Groups	740.919	2	370.459	0.569	0.569
	Within Groups	37094.779	57	650.786		
	Total	37835.698	59			
distal	Between Groups	135.982	2	67.991	0.153	0.859
	Within Groups	25390.821	57	445.453		
	Total	25526.803	59			

P<0.05 Significant.

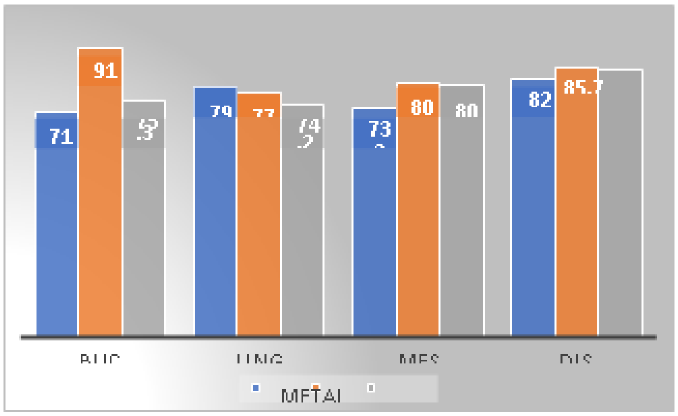
		Sum of Squares	df	Mean Square	F	Sig.
1	Between Groups	659.069	2	329.534	3.438	.039
	Within Groups	5463.910	57	95.858		
	Total	6122.979	59			
2	Between Groups	335.762	2	167.881	1.651	.201
	Within Groups	5796.799	57	101.698		
	Total	6132.562	59			
3	Between Groups	385.234	2	192.617	.856	.430
	Within Groups	12822.953	57	224.964		
	Total	13208.186	59			
4	Between Groups	1991.237	2	995.618	3.969	.024
	Within Groups	14296.759	57	250.820		
	Total	16287.995	59			
5	Between Groups	1636.482	2	818.241	3.614	.033
	Within Groups	12903.622	57	226.379		
	Total	14540.104	59			

6	Between Groups	259.415	2	129.708	2.049	.138
	Within Groups	3608.734	57	63.311		
	Total	3868.149	59			
7	Between Groups	670.596	2	335.298	3.172	.049
	Within Groups	6025.884	57	105.717		
	Total	6696.480	59			

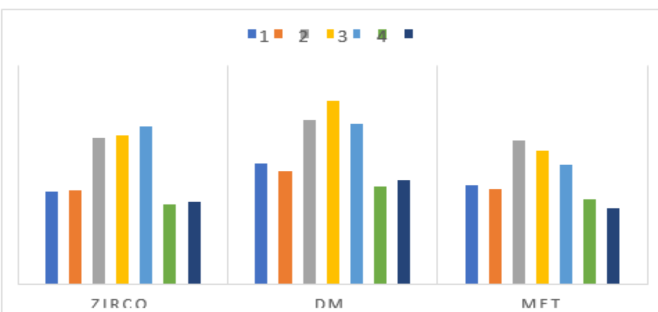
Comparison of groups using ANOVA

Comparison of axial wall adaptability of Metal ceramic copings, DMLS copings and Zirconia copings.

Graphs

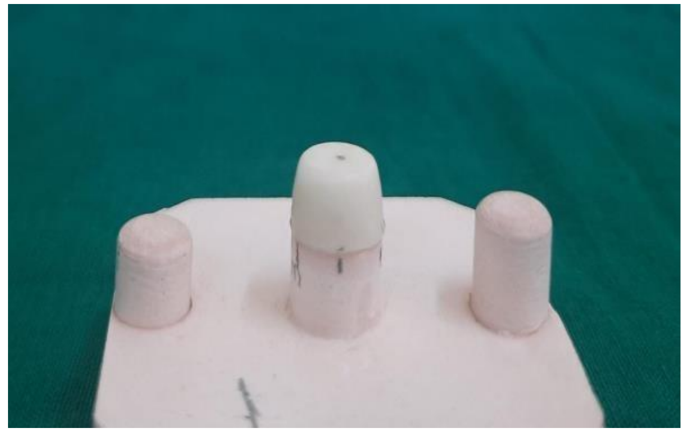


Graph 1: representing means of marginal fit of metal ceramic, DMLS and zirconia copings

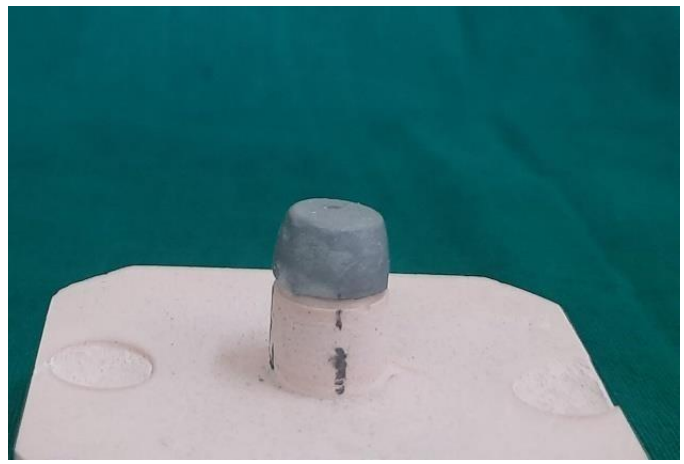


Graph 2: representing axial wall adaptability of metal ceramic, DMLS, zirconia copings

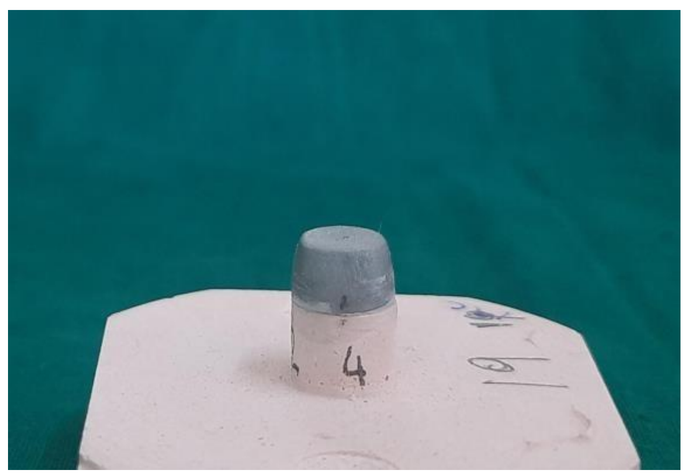
Figures 1: Master die



Figures 2: Zirconia copings after cementation



Figures 3: Dmls coping after cementation



Figures 4: Metal ceramic coping after cementation

Figures 5: Marginal fit of metal ceramic coping

Figures 6: Axial wall adapatability of zirconia coping at seven different points