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Marginal Accuracy of Cast Crowns Fabricated Using Different Investment Systems (An In -Vitro Study)

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Dr. Radhika Agnihotri
Reader, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University, Gandhinagar.

Dr. Kartik Morjaria
Specialist Prosthodontist, Aster clinics, Aster DM Healthcare, Dubai

Dr. Kalpesh Vaishnav
Professor, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University, Gandhinagar. Email: Dr_kalpnita@yahoo.com

Dr. Dipti Shah
Professor and Head of department, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University, Gandhinagar.

Dr. Ravi Joshi
Reader, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University Gandhinagar.

Dr. Miloni Bhatt
Senior lecturer, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University Gandhinagar.

Dr. Khushbu Baraiya
3 rd Year Post graduate Student, Department of Prosthodontic Karnavati School of Dentistry, Karnavati University Gandhinagar.

Keywords
All-metal crowns, Ringless technique, marginal discrepancy

Abstract
Context: Any dental restoration's marginal fit is very important for its success. The teeth and the adjacent periodontal tissues- both may suffer from an inadequate fit. Aims: to assess how various investment systems affect the marginal accuracy of cast crowns. Method: A total of 60 complete coverage crowns made entirely using metal on metal dies. The crowns were separated into 4 groups each with 15 patterns. For investing and casting a ringless system and a ring system (split) were used in group B and group A respectively. In Group C metal rings with single layer cellulose acetate liners devoid of asbestos is used and Group D metal rings with double-layer cellulose acetate liners devoid of asbestosis used. By measuring the distance with a microscope between the die's finish line and the edges of the crown, marginal discrepancy was determined. Results Groups -A, B, C, D -each had a mean marginal disparity of 113μm, 210μm, 206μm, and 161μm, respectively. The 4 groups' marginal discrepancies on each surface were compared. Of the four groups, Group A was the most accurate, while Group B was the least accurate. Conclusion: The ringless casting process can result in with better marginal fit due to accurate casting.

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1. Introduction

The amount of tooth structure present, resistance and retention form, durability of structures, marginal integrity etc. are factors responsible for the success of fixed restoration[1]. For the long-term success of metal-ceramic crowns, a good marginal fit seems to be one of the most important technical factors.[2] The luting material is exposed to the oral environment due to increased marginal discrepancies, which can cause cement dissolution and microleakage. The vital pulp might become inflamed when the cement seal becomes weak, allowing bacteria to permeate[3]. Studies among Indian population have shown, one of reason for failure of fixed restoration is due to defective margins[4].

2. Methods:

The present in vitro study was undertaken at Karnavati School of Dentistry, Karnavati University, Gandhinagar. Typodont has a supragingival chamfer finish line and an all-metal complete coverage crown (approximately 0.7 mm wide). Reservoir method of spruing was used after impression with vinyl polysiloxane material of the prepared tooth. Lining of 1mm thick, 3.5 cm long metal casting ring (of 3 cm in diameter) done with a single strip of asbestos-free cellulose acetate ring liner. The silicone crucible former was used to secure the sprued acrylic pattern after which it was sprayed with a substance that reduced surface tension. Graphite-free phosphate-bonded investment material (Wirovest) was then invested using a 3:7 mix of Special Expansion Liquid and Distilled Water. The recommended 80 gm: 12 ml powder-liquid ratio was used. Heating of the mould was done in a burnout furnace C for 30 minutes at the temperature of 250°C, and then for two hours at 950°C .This temperature was used to heat soak the mould once again for 30 minutes before casting. Co-Cr-Mo alloy (Wironit) was used for casting.

For the casting procedure induction casting machine was used. After cooling down of casting ring to room temperature, divesting from the investment was done. Sandblasting was used on the adhering investment. The isolated nodules and sprue were removed. The polished and completed metal die. (FIGURE 1)

Figure.1 : Metal Die

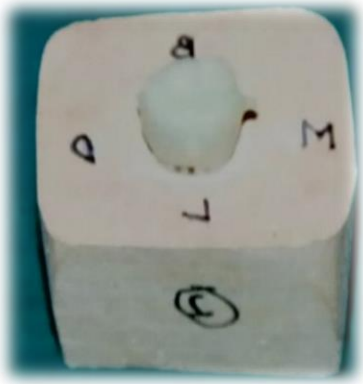

Figure.2 Wax Pattern On Metal Die

Figure.3: Metal Crown On Die

CAD/CAM machine was used to fabricate 60 similar wax patterns from the virtual image. A virtual image of the 0.7 mm thickness wax pattern was constructed over a die using the software. Four groups having same number of wax patterns are made for the study after the fabrication of the wax patterns (FIGURE 2),

1. Group A- Crowns fabricated using ringless investment technique

2. Group B- Crowns fabricated using split ring investment technique

3. Group C- Crowns fabricated using metal ring investment technique with single ring liner

4. Group D- Crowns fabricated using metal ring investment technique

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For spruing, a preformed wire (2.5 mm X 15 mm) was used. At the distobuccal cusp tip, the designs were sprued at a 45° angle. For investing graphite free Phosphate bonded investment material (Bellavest T) was used. With distilled water, the investment material's concentration diluted to 80%. We used the recommended powder to liquid ratio of 100 gm: 23 ml. With the exception of group A, where the removal time of the moulds from the ring (after the initial setting of investment material) is for 10 minutes, the investment rings were allowed to set undisturbed for 60 minutes following vacuum mixing (60 seconds) and pouring the mix into casting rings while keeping them on a vibrator. As long as a ring was created, each pattern was individually invested in one of them.

After 60 minutes, the silicone crucible former was taken out. After being heated for 40 minutes at 280°C, the mould was heated in a burnout furnace for two hours at 980°C, leaving it for 60 minutes to heat soak at this temperature. This temperature was used to heat soak the mould once more for 60 minutes before casting. Wirolloy, a Ni-Cr alloy, was utilised for casting. When it was time to cast, the pre-weight ingots were melted using a blowtorch. Following the same steps as during the manufacturing of the metal die (FIGURE 3), 60 castings were retrieved and sorted into four groups (group- A, group -B, group- C, and group- D), each consisting of 15 castings.

On the metal die, specified areas were marked in the middle of various surfaces - buccal, lingual, mesial, and distal for the evaluation of marginal fit. For application of a force (standard) to the castings to seat them on the metal die, use of a holder was done. Using a stereomicroscope and image analysis software, the vertical marginal difference was measured.(IMAGE J) (FIGURE 4,5)

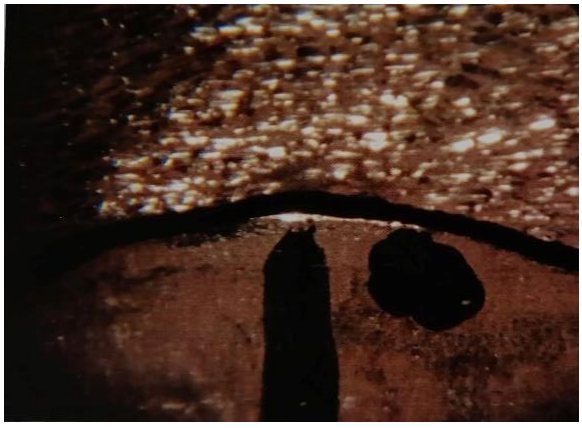

Figure 4: MARGINAL GAP IN STEREOMICROSCOPE

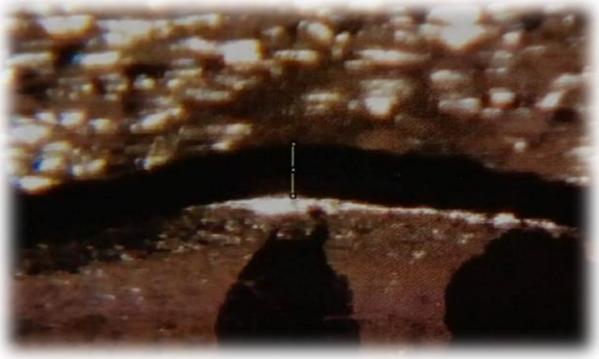

Figure 5: MARGINAL GAP IN IMAGE J SOFTWARE

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3. Results

The marginal gaps were calculated on every surface of a crown individually and the mean of the marginal gaps on all surfaces was calculated and considered as the marginal gap for the particular crown. The mean marginal gaps of 15 crowns of each group was calculated and considered as the marginal gap for that particular group. . An extended study of the effect of the investment system on the buccal, distal, lingual and mesial surfaces was also done by calculating the mean values for the individual surface. The mean values of marginal gaps for the particular groups and third standard deviations were calculated. The data was analysed by a One Way Analysis of Variance test and the Post Hoc Tukey HSD test. Intergroup comparisons were done using the Post Hoc Tukey HSD test for the individual surfaces as well.

TABLE 1: ONE WAY ANOVA FOR EFFECT OF DIFFERENT INVESTMENT SYSTEMS ON MARGINAL GAP OF CAST CROWNS

INVESTMENT SYSTEM	N	MEAN	STD DEVIATION	STD. ERROR	MINIMUM	MAXIMM	COEFFCIET OF VARIANCE
GROUP A	15	113.50	10.154	2.622	94.25	138.00	8.98
GROUP B	15	50	16.612	4.289	161.50	238.00	7.89
GROUP C	15	206.483	12.540	3.238	192.75	244.50	6.07
FROUP D	15	161.033	4.341	1.121	153.75	170.00	2.70

One-way Analysis of Variance (ANOVA) test is used.

TABLE 2: MULTIPLE COMPARISONS OF MEAN MARGINAL GAPS WITHIN AND BETWEEN THE GROUPS

COMPARISON	SUM OF SQUARES	DF	MEAN SQUARE	F	ANOVA P VALUE
BETWEEN GROUPS	93908.970	3	31302.990	225.539	<0.0001
WITHIN GROUPS	7772.342	56	138.792		
TOTAL	10168.311	59			

*P value <0.05 statistically significant

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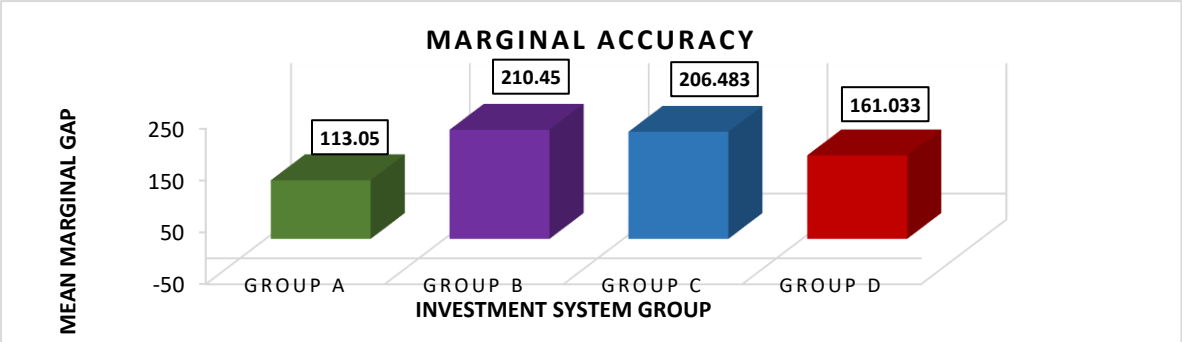
TABLE 3: INTER RELATION OF EFFECT OF DIFFERENT INVESTMENT SYSTEMS ON THE MARGINAL GAP OF CAST CROWNS

(I) GROUP	(J) GROUP	MEAN DIFFERENCE (I-J)	STD. ERROR	P VALUE	95% CONFIDENCE INTERVAL	
					LOWER BOUND	UPPER BOUND
GROUP A	GROUP B	-97.400	4.302	<0.0001	-108.791	-86.009
GROUP A	GROUP C	-93.433	4.302	<0.0001	-104.824	-82.009
GROUP A	GROUP D	-47.983	4.302	<0.0001	-59.374	-36.593
GROUP B	GROUP C	3.967	4.302	0.793	-7.424	15.357
GROUP B	GROUP D	49.417	4.302	<0.0001	38.026	60.807
GROUP C	GROUP D	45.450	4.302	<0.0001	34.059	56.841

*p value<0.05 statiscally significant



4. Marginal Accuracy

The mean marginal gap values (μ) with standard deviations (SD) in Group -A, Group- B, Group- C and Group -D were 113.05±10.154. 210.45±16.612, 206.48±12.540 and 161.03±4.341 respectively, where Group- A showed the least mean marginal gap and Group- B showed the highest mean marginal gap. In all groups, the ascending order for mean marginal gap values was Group- A (113.05±10.154) < Group- D (161.03±4.341) < Group- C (206.48±12.540) < Group- B (210.45±16.612). There was a significant influence of the different investment technique on the marginal accuracy of cast crowns (ANOVA p value < 0.0001), showing that Group A was the most accurate and Group B was the least accurate of all four groups. (Table 1)

Table 2 shows multiple comparisons of mean marginal gaps within and between the groups A, B, C and D using one way analysis of variances (ANOVA). It showed that the variances were statistically significant (P-value < 0.0001).

Table 3 shows statistically significant difference between the mean marginal gap values (μ) when Group- A was compared with Group- B (p value < 0.0001). When Group- A and Group-C were compared, the difference between the mean marginal gap values (μ) was statistically significant (p value 0.0001).There was difference statistically significant difference between the mean marginal

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gap values (µ) when Group A was with Group D compared (p value <0.0001). The difference between the mean marginal gap values (µ) of Group-B and Group-C was statistically significant. (p value 0.793). The difference between the mean marginal gap values (µ) of Group-B and Group-D was statistically significant (p value 0.0001). The difference between the mean marginal gap values (µ) of Group-C and Group-D was statistically significant (p value < 0.0001).

5. Discussion

For the success of any fixed restoration, the main principles of tooth preparation should always be kept in mind. The longevity of any fixed restoration depends on many factors such as the amount of tooth structure present, retention and resistance form, structural durability, marginal integrity etc. Of all these factors, the marginal integrity of the restoration relates to the accuracy of the restoration. The better the marginal integrity, the more accurate is the restoration. Many factors affect the marginal accuracy of fixed restorations. These include the undercuts, taper, and finish line of the abutment tooth preparation, the impressions, the working cast, the thickness of the die spacer, the length, shape, and diameter of the sprue design, the investment technique employed, the length, diameter, and thickness of the casting ring, the thickness of the ring liner, the type of luting cement, the surface roughness, etc. Good fit of the construction is one important requisite [5-6] for good clinical results of fixed dental prostheses which in turn require for a good prognosis[7-10]. According to a study done by Foster[11] failed FDPs, an unacceptable fit was a major element in this technical complication. Unacceptable marginal gaps could lead to cement washout[12] and subsequent biological problems such pulpitis, periodontal disease, and secondary caries[13-14].

Marginal gaps may result in wear or dissolution which may result in cement loss. Marginal gaps and marginal misfit may lead to secondary caries which may affect the pulp life of the crowned tooth. According to McLean and von Fraunhofer maximum gap should be 120 microns to make single tooth restoration clinically acceptable. According to Moldovan et al, marginal misfit up to 200-300 µmas acceptable and 100 µm good . As per some authors, margins up to 160 µm might be tolerable. Gingival margin range from 34-119 µm is acceptable according to Christensen. Casting done by conventional metal ring result in castings with less marginal misfit according to M Kalavathi's study. But Sandeep Kumar[23] concluded that ringless casting result in casing is showing more marginal accuracy than casting made with ringless casting system.

The properties of dental waxes, die materials, investment materials, advanced procedures that enable more accurate control of mould expansion, modifications to the compositions of dental alloys, and improved fitting techniques have all led to the refinement of the casting process. [24-30].

The fabrication of the crown is a technically challenging procedure despite the level of precision that may be achieved. The following list of five positive and negative changes from the tooth to the crown[31]. These include the metal cast, wax pattern, refractory investment mould, impression, and die.A gypsum-bonded-type –investment was used in the beginning.[32-33]

Three methods are currently in regular use to compensate for metal shrinkage while it cools[34]: (1) three types of expansion affect investments: (1) setting expansion, (2) hygroscopic expansion, and (3) thermal expansion. Capacity of Gypsum to withstand heat without decomposing is up to 1200°C without decomposing.[35-36], making it heat-resistant enough to use without the addition of additional refractory materials. However silica is added to the investment to overcome shrinkage of gypsum at this temperature to to control the dimensional changes when the investment is heated. The use of metal ring necessary to protect the investment during casting forces as silica reduces the compressive strength. To withstand firing cycle of porcelain without noticeable distortion in cermic-metal technology, use of investment materials like phosphate bonded investments started due to their higher resistance power against high temperatures and high stresses during casting – Therefore, in the present study, to maintain the standardization, phosphate bonded investment material (Bellavest T) was used for investing in all groups.

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Ringless technique is introduced for Fixed prosthodontic technique which was used for The production of frameworks for RPDs(removable partial dentures) The restriction of thermal expansion due to use of metal ring can be avoided by using a ringless approach.

In the current investigation, a Co-Cr die with a thick chamfer finish line was built to prevent any scratching and breakage during test operations. The hardness and other characteristics of the alloy were taken into consideration when creating this die. To more accurately analyse the marginal fit, the chamfer width was notably increased from the standard 0.5 mm to around 0.7 mm. This was done to reduce the risk of error and to stop any damage from happening during the finishing process.

In this study, Group -A consisted of crowns fabricated using the ringless investment technique. Group -B consisted of a split casting ring investment system. In this system, after the initial set of the investment material, the split ring was opened and the flexibility of the ring allowed for the expansion of the investment material. Groups -C and D consisted of metal casting ring investment techniques using single and double layers of ring liners. Double ring liners were used in case more expansion of the investment material was required. Due to the entire expansion of the mould during the setting of the investment occurring uniformly and without any restrictions in all directions, the results showed that all of the castings in Group A shows the least vertical marginal inaccuracy. The marginal discrepancy was 113.05 µm which is in acceptable range of 120 µm [21]. The Group D castings' vertical marginal difference (161.03 µm) was just higher than that of the Group A castings. The gap is acceptable, according to the research by Moldovan et al, even if this discrepancy is outside of the clinically acceptable range.[17]

The vertical marginal discrepancy of Group -C castings followed Group - D castings with the mean marginal gap of 206.48 µm. This can be explained by the fact that the Crowns belonging to Group C were fabricated using a metal ring investment technique with a single ring liner as compared to Group D in which a double ring liner was used. The double ring liner therefore allowed for greater expansion of the investment mold. Therefore, more compensation for casting shrinkage was achieved, thereby producing more accurate cast crowns. The maximum marginal gap was observed in Group B (210.3µm) which was also in the clinically acceptable range. This group was the least accurate of all.

6. Conclusion

Fixed restorations in dentistry are those which cannot be readily removed from the oral cavity. For any such restoration to survive and be successful, many criteria need to be fulfilled. Adequate amount of tooth structure should be present after tooth preparation, the tooth should allow for proper retention and resistance form, the marginal fit of the prosthesis should be as accurate as possible etc. If the marginal fit of the restoration is not accurate, it may lead to luting cement dissolution. This is followed by bacterial invasion and secondary caries and therefore failure of the restoration. To avoid such complications, it is necessary to ensure the restoration fits adequately.

In the present study, the effect on the marginal accuracy of cast crowns by different investment systems viz. ringless investment system, split casting ring investment system and metal casting ring investment system with single and double layers of ring liners, was evaluated. A lower molar on a typhodont was prepared to receive a full coverage all metal cast crown and a metal die of the same was fabricated from it. 60 wax patterns for the cast crown were prepared using the CAD/CAM technology and were divided into four groups as stated earlier. The cast crown that were prepared were then seated individually on the metal die and analyzed under a stereomicroscope. The images were then transferred to a computer and the marginal gap was measured using image-analysis software. The mean marginal gap for each group was calculated and results from all groups were evaluated and compared using ANOVA test and post Hoc Tukey Analysis.

The result revealed that the difference investment systems have a significant effect on the marginal accuracy of cast crowns. According to the analysis, least marginal gap was found in the ringless investment system. This was followed by metal ring

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using double ring liner, metal ring using single ring liner and finally split metal ring investment system.

Within the limitations of this in vitro study, the marginal accuracy of cast crowns fabricated from different investment systems was compared and the following conclusions were drawn:

1. The different investment systems have a significant effect on the marginal accuracy of cast crowns.

2. The marginal accuracy of crowns fabricated from all investment systems were in the clinically tolerable range.

3. Comparative analysis of the effect of different investment systems on the marginal accuracy is as follows-

a) Ringless investment system -Marginal gap in this group was least of all. It means it is the most accurate of all.
b) Split metal ring investment system- Marginal gap in this group was the highest which means it is the least accurate investment system.
c) Metal ring investment system with single cellulose ring liner Marginal gap in this group was significantly more than that of Ringless investment system and Metal ring investment system with double cellulose ring liner. Although the marginal gap in this group was lesser than that of Split metal ring investment system, the difference was not significant.

d) Metal ring investment system with double cellulose ring liner—In this group, the marginal gap was significantly smaller than it was in the Metal ring investment system with single cellulose ring liner and the Metal ring investment system with double cellulose ring liner, but it was still significantly higher than the Ringless investment system. In light of the other three investment strategies, this one was the second best.

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