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A Comparative Evaluation of Casting Accuracy by Two Different Methods of Die Spacer Application – An In Vitro Study

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Abstract: The margin is one of the components of the cast restoration most susceptible to failure, both biologically and mechanically. Obtaining a good marginal seal is one of the most important factor in determining the long term success of cast restorations. The purpose of the study was to comparative evaluate the casting accuracy by axial coverage of the die spacer 1.00 mm short from the finish line and complete axial coverage of the die spacer. Irrespective of the method of the die spacer application, all the castings showed deficiency in the marginal fit. Efforts were made to select and utilize standard method. The enhancement of marginal fit with incomplete axial die spacer coverage by providing an area of close adaptation near the marginal area, thereby improving the marginal seal and thus reducing the dissolution of cementing media is of great clinical significance. Increased casting accuracy with die spacer application short by 1.00 mm from finish line could be due to the reason that unpainted area will ensure an area of close adaptation at the margin. From this study, it is clear that the die spacer application short by 1.00 mm from finish line gives better marginal adaptation to castings when compared to full length die spacer application.

Keywords: Die spacer, Finish line, Cast restoration, Casting accuracy, Marginal fit.

INTRODUCTION

Obtaining a good marginal seal is one of the most important factor in determining the long term success of cast restorations. The incomplete fit of full cast crown restorations remains a critical problem for dentists, leading a scope for many researchers to study this problem [1]. Because of deficiencies inherent in the dental casting technique, a gap of varying width is likely to occur between a casting and the tooth, both internally and at the margin. Despite the technological advancements in terms of the improvement of casting techniques, die fabrication, waxing pattern and coping fabrication, a discrepancy remains between the restoration's margin and the cervical edge of the prepared tooth. Schwartz [2] has explained that there are three determinants of marginal adaptation and those were tooth preparation, material used and cement film thickness.

Early closure of the space between the casting and the axial walls of the preparation during initial stage of cementation results in an obstruction of flow and a consequent stagnation of cement at the occlusal portion [3].

The complications caused by incomplete seating of crown are creation of premature contact; alteration of contact areas with adjacent teeth; a reduction in crown retention by 19% to 32% and discrepancy of marginal fit of the crown [4]. Extensive efforts have been made and new techniques evolved to produce well fitting cast restorations for the purpose of reducing the film thickness and to minimise the cement line exposed to oral fluids. Different techniques have been in use to improve the seating of castings and to eliminate the resistance of cementing materials that prevent cast restorations from being seated completely. These techniques are burnishing [5], venting and internal relief [6]. The most common and effectively used method for internal relief is by using paint-on die spacers.

As far as requirement of die spacer is concerned, it is proved beyond doubt regarding its application but the controversy remains whether die spacer should cover the die completely or not, in order to get least marginal discrepancy. Therefore the present in-vitro study was planned.

MATERIAL AND METHODS

This prospective, in vitro study was conducted in Department of Prosthodontics and Department of Mechanical Engineering. The purpose of the study was to evaluate the casting accuracy by complete axial coverage of the die spacer and by axial coverage of the die spacer 1.00 mm short from the finish line and comparing the accuracy of casting with these two methods of die spacer application. Efforts were made to select and utilize standard method.

Sharpness of the margin is considered to be the characteristic of dental castings most dependent on the castability of the alloy used.

The materials and methods used in this study have been described under the following subheadings:

- Fabrication of the master die.
- Preparation of the stone dies.
- Die spacer application.
- Preparation of wax pattern.
- Fabrication of test casting.
- Evaluation of margin of test crowns.

Fabrication of the master die

A test was designed to examine the sharpness of the margin of a test crown. The design selected for a test casting represents a full crown for fused porcelain. A stainless steel die in cylindrical form was machined at the Workshop, Department of Mechanical Engineering and a convergence angle of 10^0 was given to the die. A height of 12.00 mm and a diameter of 10.00 mm were given to the die. A finish line with an angle of 30^0 and 1.00 mm width was produced. A shallow axial groove was given for orientation of casting during seating.

Cylindrical metal tray was fabricated for the purpose of impression making of master die in order to prepare stone dies.

Preparation of stone dies

Impressions of the master die were made using elastomeric impression material (Aquasil Ultra LV, DENTSPLY Caulk, USA) in a cylindrical metal tray. The impressions were then poured in die stone (ultrarock, KALABHAI DENTAL PRIVATE LTD.), according to manufacturer's instructions. A total of 10 such dies were poured. After the stone was allowed to set for a minimum of one hour, the dies were recovered. The dies were divided into Group I and Group II consisting of 5 dies in each group. The dies in group I was numbered as 1, 2, 3, 4, and 5. The dies in group II were numbered as 6, 7, 8, 9, and 10.

Die spacer application

The dies were allowed to dry before die spacer application for 24 hours at room temperature. The dies were coated with Tru-fit die spacer (George Taub Products, NJ) available as silver and gold coloured suspensions, the application being carried out by alternating silver and gold spacer coating as per manufacturer's instructions. About 5 minutes of drying time was allowed between each coating. Four layers of die spacer were applied in alternative layers of silver and gold since the recommended thickness of die spacer ranges from 20 µm to 40 µm. Care was taken not to clog the orientation groove.

In Group I, for all the five dies the walls of the preparation were coated 1.00 mm short of finish line. A metal ring with a thickness of 1.00 mm was used to facilitate the same. In Group II, all the five dies were coated with die spacer upto finish line.

Preparation of the wax pattern:

The stone dies were sprayed with a die lubricant (S. K. Industries). The excess lubricant was removed by blowing with an air syringe. Wax patterns were prepared by dipping technique with dipping wax (YETI DENTAL). Vacuum formed sheet of 1mm thickness was adapted over the stone die using pressure moulding machine (Biostar). Then over to the vacuum formed sheet silicon putty (Aquasil putty, DENTSPLY Caulk, USA) was adapted to obtain silicon putty mould. A silicon putty mould was used to ensure uniformity of the wax patterns. The margins of the patterns were finished under magnifying work lamp light (Flexible Arm Illuminated Magnifier; Lensel Optics Pvt. Ltd. Pune, India) and then sealed.

All the 10 patterns (five from Group I and five from Group II) were immediately sprued and then carefully mounted to the crucible former. It was then coated with a surface tension reducing agent (Debubblizer; Prime Dental Products Pvt. Ltd).

Fabrication of the test casting:

A single layer of ceramic liner 1mm thick (Keraviles-Dentaurum) was adapted to the casting ring and moistened by dipping in a bowl of water. Bellasun (Bego) was mixed as per manufacturer's recommendation. The investment was vacuum mixed in vacuum mixing machine (Cuumyx Labo-14; Confident, India) for 60 seconds and then used to invest the patterns. The investment was allowed to bench set for one hour before doing burnout.

The casting ring was placed in a burnout furnace (Ambassador R; Unident, Instruments (India) Pvt. Ltd.) at room temperature and the temperature was raised to 250^0 C and held for 60 minutes. Thereafter the temperature was raised to 950^0 C and held for 30 minutes.

After completion of the burnout, the casting procedure was carried out in an induction casting machine (Fornax; Bego) using MEAlloy (Nickel-Chromium Alloy; Dentsply, Caulk).

The casting ring was bench cooled to room temperature. The castings were retrieved manually and airborne-particle abraded (Santer Labo-16; Confident) with 50 mm aluminium oxide abrasive under 2-bar pressure for 5 seconds to remove residual investment. The marginal fit was checked under magna light. (Flexible Arm Illuminated Magnifier; Lensel Optics Pvt. Ltd. Pune, India).

Evaluation of margin of test crowns

Sharpness of the margin can be considered to be the most dependent character of a dental casting. Deficiency in reproduction of a sharp margin of 30^0 on the test crowns in the two groups was used as the castability standard.

The margins of test casting of Group I (5 test crowns numbered 1, 2, 3, 4 and 5) and Group II (5 test crowns numbered 6, 7, 8, 9 and 10) were examined by an indirect method using an impression. The casting was positioned centrally in a ring filled with impression material (Aquasil Ultra LV, DENTSPLY Caulk, USA).

Cast specimens were evaluated for marginal rounding using a methodology proposed by Brockhurst et al and Chan et al. The method is based on an indirect technique using a dental impression material to record the crown margin configurations. Cast specimens were fixed to the vertical shaft of a dental surveyor (Unident, Instruments (India) Pvt. Ltd.), with the help of sprue and their margins were lowered into a polyvinyl chloride (PVC) ring filled with a light-body condensation silicone impression material (Aquasil ULtra LV; DENTSPLY Caulk, USA). After material polymerization, patterns and cast specimens were removed from the PVC ring. Each silicone impression was then cut into 4 equal-size segments using a razor blade (Vidyut; Super-Max) and cutting guides located in the PVC ring (Finolex). The silicone sections were positioned over a glass slab. The superior face for each section was marked with a permanent marker pen (CD Marker; Camlin Limited, Mumbai, India). Each impression section had 2 faces, but only the marked face was measured. Impressions of all the ten castings were precisely cut and labelled.

The quality of the edge of the casting was expressed in terms of deficiency (d) between the edge of the casting obtained and the theoretical sharp edge.The discrepancy of the margin on each segment was examined by using a profile projector V-12 (Nikon) using the profile, the radius of the margin was measured for each specimen. The readings were tabulated. The deficiency (d) was then calculated by using the formula;

Deficiency (d) = 2.70 x R (radius).

From each casting, four measurements were obtained. Thus from the twenty measurements of Group I and twenty measurements of Group II were obtained.

Experimental values of deficiencies like average, coefficient of variation and 95% confidence level were found in both the groups for comparison between the two different methods of die spacer application. Students‘t’ test was used to find the significance of difference between the two die spacer applications.

RESULTS

The study was carried out to evaluate the casting accuracy by two different methods of die spacer application. Test castings obtained by incomplete and complete axial die spacer coverage were evaluated by an indirect method by making impression of the castings. The impressions were sectioned and discrepancy of the margin on each segment was measured with the help of a profile projector. The quality of margins of castings obtained by complete and incomplete axial die spacer application was expressed in terms of deficiency.

Experimental values of deficiencies like average, coefficient of variation and 95% confidence level were found in both the groups for comparison between the two different methods of die spacer application. Students‘t’ test was used to find the significance of difference between the two die spacer applications.

Table-1 shows the values of deficiency measured in 20 different segments with die spacer application short by 1.00 mm from finish line.

Table-2 shows the values of deficiency measured in 20 different segments with full length die spacer application.

Table-3 shows the level of radius on margin of test castings by two different methods of die spacer application.

Table-4 shows the range, mean, coefficient of variation and upper 95% confidence level of deficiency for two different methods of die spacer application.

Table-5 shows the comparative statistics between deficiencies between the two different methods of die spacer application.

Graph-1 shows the comparison of mean radius on margin of test castings.

Graph-2 shows the deficiency in the accuracy of castings between the two methods of die spacer application.

Graph-3 Shows the deficiency range of castings.

Table-1: Die Spacer Application Short By 1.00 Mm From Finish Line (GROUP-I)

SAMPLE NO.	DIAMETER (mm)	RADIUS (R)(mm)	DEFECIENCY (D = 2.7 X R) (mm)	DEFECIENCY (µm)
1-A	0.021	0.0105	0.02835	28
1-B	0.026	0.0130	0.03510	35
1-C	0.027	0.0135	0.03645	36
1-D	0.025	0.0125	0.03375	34
2-A	0.020	0.0100	0.02700	27
2-B	0.018	0.0090	0.02430	24
2-C	0.019	0.0095	0.02565	26
3-D	0.021	0.0105	0.02835	28
3-A	0.022	0.0110	0.02970	30
3-B	0.020	0.0100	0.02700	27
3-C	0.018	0.0090	0.02430	24
3-D	0.025	0.0125	0.03375	34
4-A	0.022	0.0110	0.02970	30
4-B	0.020	0.0100	0.02700	27
4-C	0.018	0.0090	0.02430	24
4-D	0.022	0.0110	0.02970	30
5-A	0.020	0.0100	0.02700	27
5-B	0.015	0.0075	0.02025	20
5-C	0.016	0.0080	0.02160	22
5-D	0.018	0.0090	0.02430	24

Table-2: Complete Axial Die Spacer Application / Spacer Application Upto Finish Line (Group II).

SAMPLE NO.	DIAMETER (mm)	RADIUS (R) (mm)	DEFECIENCY (D = 2.7 X R) (mm)	DEFECIENCY (µm)
6-A	0.020	0.010	0.02700	27
6-B	0.030	0.015	0.04050	41
6-C	0.028	0.014	0.03780	38
6-D	0.030	0.015	0.04050	40
7-A	0.028	0.014	0.03780	38
7-B	0.022	0.011	0.02970	30
7-C	0.024	0.012	0.03240	32
7-D	0.026	0.013	0.03510	35
8-A	0.029	0.0145	0.03915	39
8-B	0.027	0.0135	0.03645	37
8-C	0.022	0.0110	0.02970	30
8-D	0.030	0.0150	0.04050	41
9-A	0.021	0.0105	0.02835	28
9-B	0.029	0.0145	0.03915	39
9-C	0.003	0.015	0.04050	41
9-D	0.026	0.013	0.03510	35
10-A	0.029	0.0145	0.03915	39
10-B	0.026	0.0130	0.03510	35
10-C	0.025	0.0125	0.03375	34
10-D	0.030	0.0150	0.04050	41

Table-3: Measurement of Radius on Margin of Test Castings

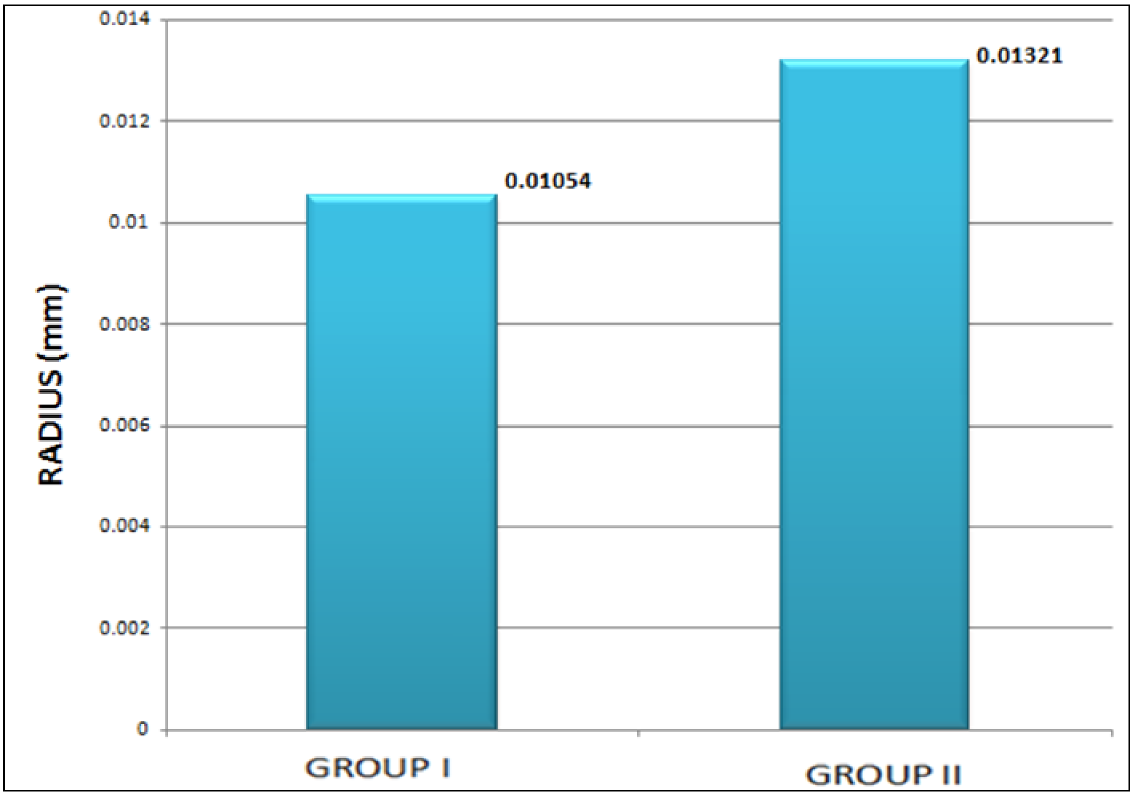
SPACER APPLICATION	n (SAMPLE SIZE)	RADIUS (mm)		
		RANGE	MEAN	S.D.
GROUP I (1mm SHORT)	20	0.0075-0.0135	0.01054	0.00164
GROUP II (FULL LENGTH)	20	0.010-0.015	0.01321	0.00168

Table-4: Experimental Values of Defeciencies of Castings

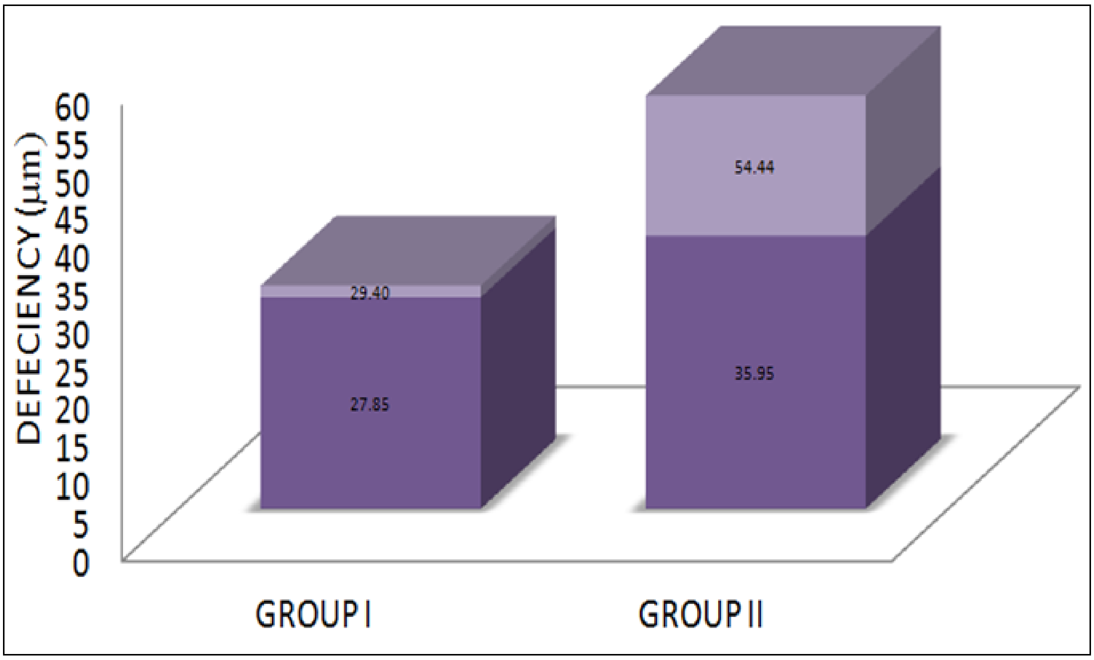
SPACER APPLICATION	RANGE (μm)	MEAN (μm)	CO-EFFICIENT OF VARIATION (%)	95% CONFIDENCE INTERVAL
GROUP I (1mm SHORT)	20-36	27.85	15.79892	29.39802
GROUP II (FULL LENGTH)	27-41	35.95	13.74131	54.43638

Table-5: Comparison of Defeciencies of Castings

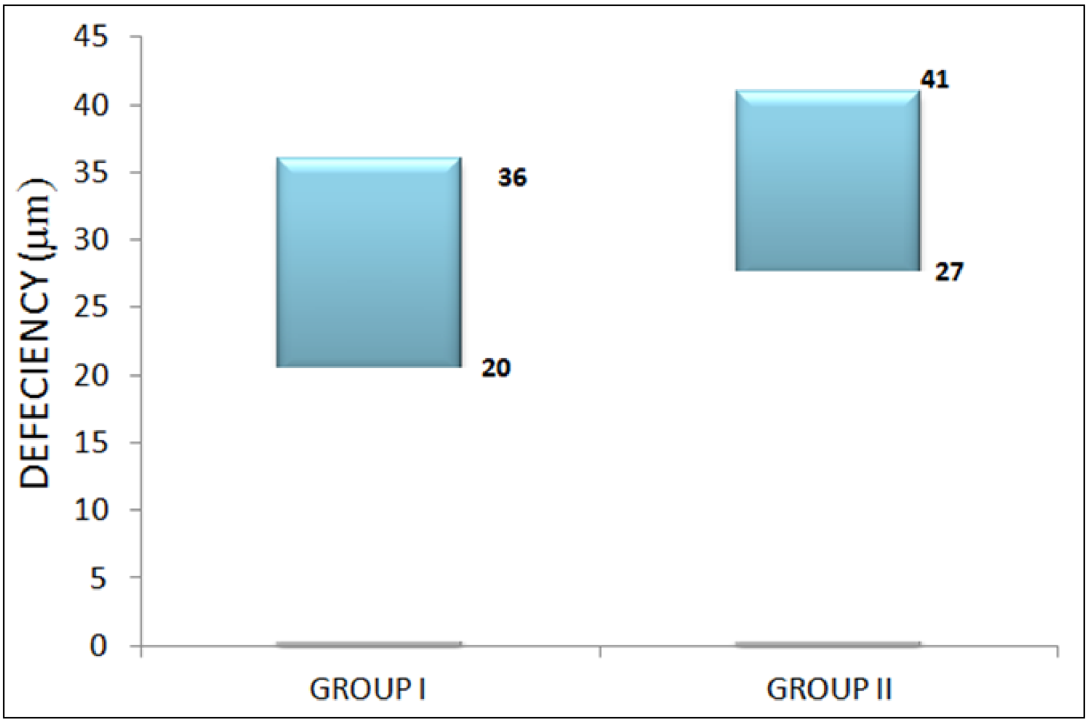
SPACER APPLICATION	n (SAMPLE SIZE)	DEFECIENCY (μm)			't' VALUE	OBSERVED 'P' VALUE	SIGNIFICANCE
		MEAN	S.D	S.E			
GROUP I (1mm SHORT)	20	27.85	4.40	0.98	5.76	0.000	P < 0.001
GROUP II (FULL LENGTH)	20	35.95	4.94	1.00			



Bar Graph-1: Mean Radius on Margin of Test Castings



Bar Graph-2: Defeciency (µm), In The Accuracy of Castings Between Two Die Spacer Applications



Bar Graph-3: Defeciency (Range) of Castings

The above observations shows that die spacer application 1.00 mm short of finish line gave more accurate test castings with less deficiency value. The minimum value of deficiency in 1.00 mm short die spacer application was only 20 µm compared to 27 µm in full length die spacer application.

The mean deficiency in die spacer application 1.00 mm short of finish line was 27.85 µm which was significantly less when compared to mean deficiency of 35.95 µm for full length die spacer application. The mean difference of deficiency between two groups of die spacer application was 8.10 µm (23.03 %). The difference was statistically highly significant ($P < 0.001$).

The above statistical analysis revealed that incomplete die spacer coverage (1.00 mm short of finish line) results in more accurate castings with less marginal deficiency when compared to complete axial die spacer coverage.

DISCUSSION

Dental casting, because they are produced by many combinations of technique, materials and technical skill, can exhibit great variation in excellence and serviceability. Criteria for good casting are one which seats accurately on the tooth, is adequately retained, restores function & esthetics and exhibits no appreciable cement line at the margin.

Marginal adaptation between a tooth and a fixed prosthesis is of vital importance to increase the longevity of the restoration by reduction of exposure of cement at the margins and prevention of caries. The more accurate the casting fits the prepared tooth; the more difficult it is for cement that gets trapped between the crown and the tooth to escape leading to incomplete seating and crown elevation.

The most common and effectively used method for internal relief is by using paint-on die spacers. The technique of paint-on die spacers is used so that a uniform and specific amount of space between the tooth and the casting allows the cement to escape and decrease the hydrodynamic resistance to seating. The advantage of this method is that it is simple, time saving and inexpensive. Eames *et al*., [7] found that cemented full crowns relieved with die spacers were 25 % more retentive than unrelieved cemented full crowns. A clinically accepted relief is considered to be 20 to 40 µm [4].

The standard procedure of die spacer application is that the walls of preparation are coated 0.5 to 1.00 mm short of finish line. Because there should be close adaptation of casting to the tooth to reduce dissolution of cementing medium at the margins. However Rafel Grajower [8] found that leaving the cervical part of axial wall near the margin uncovered with spacer negates the effect of spacer on the remaining portion almost completely. It is proved beyond doubt regarding necessity of using a die spacer but the dilemma remains whether die spacer should cover the die completely or not, in order to get least marginal discrepancy.

Increased casting accuracy with die spacer application short by 1.00 mm from finish line could be due to the reason that unpainted area will ensure an area of close adaptation at the margin. This area plays a significant role in better seating leading to improved marginal adaptation. It will also give a greater marginal fit thereby reducing the film thickness of luting agent at the margins. Theoretically, the application of die relief decreases discrepancy in restoration to tooth fit significantly and the marginal area of the casting are more accurately related. This plays a greater role in better seating of the casting.

A factor which might have lead to increased casting accuracy with incomplete axial die spacer application in comparison with complete axial die spacer application could be due to difference in thickness of metal between the two in the marginal area. Incomplete axial die spacer application will have an increased metal thickness in the marginal area due to absence of die spacer in that region. It is seen that the amount of distortion or warpage while cooling in the casting procedure are more in thin metal section than compared to thick metal section. Comparatively cooling occurs at slower rate in thicker section than compared to thin metal sections. It is seen that the amount of warpage that takes place is governed mainly by the overall casting length and differences in metal thickness [6].

From this study, it is clear that the die spacer application short by 1.00 mm from finish line gives better marginal adaptation to castings when compared to full length die spacer application. The enhancement of marginal fit with incomplete axial die spacer coverage by providing an area of close adaptation near the marginal area, thereby improving the marginal seal and thus reducing the dissolution of cementing media is of great clinical significance.

CONCLUSION

From the results obtained in this study, the following conclusions can be drawn.

- Irrespective of the method of the die spacer application, all the castings showed deficiency in the marginal fit.
- The die spacer application short of 1.00 mm has showed less amount of deficiency.
- The complete axial die spacer application resulted in greater deficiency.

Hence, application of die spacer 1.00 mm short from finish line on the die is beneficial to reduce the discrepancy in marginal fit and also to reduce the exposure of the cement at the margins.

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