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A Comparative Evaluation of Conventional Vs Accelerated Casting Technique, as Regards Marginal Fit and Surface Roughness

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Abstract:
Introduction: *Several materials and methods have been used for ceramometal crown fabrication. Marginal fit and surface roughness are two important elements in the accuracy of casting. Conventional Technique requires 2-4 hours for completion of casting. Accelerated Technique has been attempted in an effort to achieve similar quality results in 30 – 40 minutes which is significantly time – saving. The purpose of the present study was to evaluate the marginal fit and surface roughness by comparing above two techniques.*
Methodology: *Part I of the study determined marginal fit of base ceramometal crowns with the use of phosphate bonded investment. In the conventional technique, the temperature was raised at a rate of 8°C per minute up to 427°C where it was held for* $1^1/_2$ *hour. A rate of 14°C per minute was used for the second cycle up to 815°C whereas; the invested ring for the accelerated technique was placed in an 815°C preheated furnace immediately after setting of investment, for 15 minutes . Part II evaluated surface roughness of casting made with same techniques as Part I.*
Results And Conclusion: *No statistically significant variation in the marginal discrepancy and surface roughness was observed in all the four quadrants between accelerated and conventional casting techniques. Accelerated technique was found to be definitely a time saving procedure for the dentist and the lab technician as compared to conventional technique.*
Keywords: *Accelerated casting technique, Base ceramometal alloy, Conventional casting technique, Marginal fit, Surface Roughness.*

I. Introduction

The success of the fixed restoration depends upon many factors and one of the prominent factor is the close adaptation at the margins of the cast restorations. The shortcoming or discrepancy at the margin causes accumulation of plaque, infiltration of bacteria and gradual dissolution of the luting cements and finally may cause the failure of the restoration. Marginal discrepancy has been related to the preparation of wax pattern, the property of alloy used, defect in the casting process, release of stress during casting and the properties of the investment. The most evident reason for marginal discrepancy is the inherent nature of shrinkage of molten metal on solidification. This is compensated by expanding the mould space which is achieved through the expansile properties of the investment.

Surface roughness is also a considerable factor of the cast restoration margin evenness / fineness. The internal crown surface and external crown surface fuse to make the margin of casting and here, the occurrence and ratio of surface roughness plays an important role in making the margin smooth or irregular. Internal surface roughness or a small rough nodule can result in marginal gap width and can limit uniform space for luting cement.

Refinement of casting process has evolved through enhancement of impression materials, use of die spacers, improvement in the properties of dental waxes, die materials and investment materials, superior technique that allow more precise control of mould expansion, changes in dental alloy formulations and improved fitting techniques. Conventional Technique requires minimum 1 hour bench set time for investment followed by burnout procedure before casting and the total processing needs 2-4 hours.

However, In 1988, Marzouk and Kerby proposed an accelerated casting technique to minimize the time consumed in casting procedure [1]. The Accelerated Casting Technique has been attempted in an effort to achieve similar quality results in 30 – 40 minutes which is significantly time – saving [2]. Hence, this invitro study was employed to evaluate the resultant casting qualities, in both conventional and accelerated casting technique.

II. Methodology

This invitro study was carried out to evaluate the marginal fit and surface roughness of base ceramometal crowns made with conventional casting technique and accelerated casting technique. This study was reviewed by the Institutional Ethical Committee and necessary approval was obtained.

Part-I- Determination of marginal discrepancy of complete crown casting made with conventional and accelerated casting method

A stainless steel master die was fabricated to make standardized wax pattern crowns as per the study of Konstantoulakis et al. (1998) [2] (fig.1). The master die simulated a crown preparation with 10-degree total axial wall taper. The height of the die and its occlusal diameter were 6 mm and the finish line was 90-degree shoulder and 1 mm in width. A stainless steel ring (spacer) 1 mm in height was fabricated to accurately fit on the shoulder of the die. A stainless steel former that had an opening in the centre 1 mm larger than the die in all dimensions was fabricated on which the die could be accurately positioned (fig.1). A fine coating of die separator was applied onto the die and the fitting surface of the stainless steel former.

The stainless steel former was placed on stainless steel die and filled with molten inlay wax (MDM Corporation, India). Then, the base was pressed over it. The die-former assembly was held together for 1 min. with finger pressure. The die was then separated from the former, and the wax pattern obtained. The excess wax was trimmed using a PKT no. 4 carver. A uniform thickness of 0.5 mm was obtained throughout the coping. A total of 40 wax patterns were thus fabricated on this die.

All wax patterns were divided into two groups.

- For Conventional Casting Technique- Group: I - 20 samples
- For Accelerated Casting Technique- Group: II - 20 samples

The intaglio surface of each wax pattern was carefully inspected under a stereomicroscope (×10 magnification) to ensure it was smooth and free of defects. All wax patterns were uniform with 1 mm thickness at all axial and occlusal walls.

A reference mark was scribed on the margin of each wax pattern and the margin of its respective die at four sites 90 degrees apart. After seating on the die, the distance between the margin of the wax pattern and the margin of the die was measured with a Pyromatic Binocular Microscope (x20) (B.S.Pyromatic Rtdels Pvt Ltd.) with 1 μm accuracy (fig.2). Four measurements were made for each sample and the mean value was used for calculations. An 8-gauge wax sprue (Bego Co., Germany) with a reservoir 3 mm from the end of the sprue was attached to the middle of the occlusal surface of each wax pattern.To minimize distortion, the wax pattern was sprued while it was seated on the stainless steel die. One end of the sprue was attached to the pattern at an angle of 90°. The point of attachment was flared as per the study of Konstantoulakis et al. (1998) [2]

To minimize distortion, each wax pattern was invested with Phosphate bonded investment (Deguvest: Dentsply, India Pvt.Ltd.) immediately after all measurements were completed. Casting rings, 39 mm diameter and 49 mm length were used. Each casting ring was lined with one non-overlapping layer of cellulose ring liner, placed 3 mm short from end of the ring. A 6-mm distance was provided between the crown margins and the top of the casting ring. Investing procedures were same for both the conventional casting technique and the accelerated casting technique. Only bench setting times were different for both the techniques. For conventional casting technique, it was 30 minutes and for accelerated casting technique, it was 15 minutes; according to Konstantoulakis et al. (1998) [2] and Krishna Mohana T. et al. (2009) [3]. After investing, the invested ring was kept at room temperature.

A 2-stage wax elimination cycle was used for the conventional technique in accordance with the manufacturers' recommendations. One ring at a time was placed in the centre of an electric furnace at room temperature. The temperature was raised at a rate of 8°C (15°F) per minute up to 427°C (800°F) where it was held for $1^1/_2$ hour. A rate of 14°C (25°F) per minute was used for the second cycle up to 815°C (1500°F). Heat soak times at 815°C were based on the manufacturers' recommendations. The invested ring for the accelerated technique was placed in an 815°C preheated oven for 15 minutes as per the study of Konstantoulakis et al. (1998) [2]

All casting procedures were performed in an Induction Casting Machine (Ducatron). Two ingots of a nickel chromium ceramometal alloy (ME Alloy) (Dentsply:India Pvt Ltd.) were used for each casting. All rings were bench cooled to ambient room temperature after casting. After devesting, all castings were carefully cleaned. The sprues were cut with the help of Carborundum Disc. The casted devices were sandblasted with 50 μm $A1_2O_3$ particles under 30 psi pressure from approximately 5 cm distance. The direction of the nozzle was 90^0 to the casting surface.

The intaglio surface of each casting was examined under a stereomicroscope (×10 magnification) and all apparent oxide, residues and nodules were removed with a No. 1⁄2 or No. 1 round carbide bur. The castings were then cleaned with distilled water in an ultrasonic cleaner for 12 minutes and then dried.

Measurements of marginal discrepancy-

Each casting was seated on the die under a constant load of 500 gm. applied on the occlusal surface for 10 seconds (fig.3). Measurements were repeated under the same conditions and between the same reference marks as described for the wax patterns. The distance between the wax pattern margin and die margin (fig.4.a) was subtracted from the respective distance measured between the metal crown and die margins (fig.4.b). The resultant measurement was the net "marginal discrepancy." The use of a spacer between the margins of the wax pattern and the shoulder of the die made it possible to detect both expansion and shrinkage discrepancies at the marginal areas of the castings. A value of 1mm, which was occupied by spacer (a part of the die), was subtracted from all the measurements. Marginal discrepancy values were compared between the castings made with the conventional technique and those made with the accelerated technique.

Part II—Evaluation of surface roughness of castings made with a conventional and an accelerated casting method

Small pieces 1 × 1 × 1 mm of blue inlay wax were invested and cast following the same procedures as in part I. The castings were not sandblasted but instead were carefully cleaned in an ultrasonic cleaner for 12 minutes. A total no. of 20 samples was prepared. After the specimens were rinsed with water and dried, the Stub Preparation of samples was done. A SC7640 Auto/Manual High Resolution Sputter Coater, (Quorum Technologies Polaron® EM), was used to coat each specimen with a gold – palladium sputter coating. The specimens were then examined using a LEO 430 Field Emission Microscope, at 15kV. The magnified (x250) Scanning Electron Microscopic photomicrographs were then visually evaluated. In each sample, three areas of highest concavity and convexity were measured using KLONK Image Measuring Software (fig.5). The mean value of the three measurements was used for calculations.

III. Results:

Accelerated casting technique exhibited 0.1525mm of mean marginal discrepancy for Group-II which was statistically non-significant compared with conventional casting technique which exhibited mean of 0.1540mm. It means that no superiority of one technique could be established over the other. Accelerated casting technique was found to be definitely a time saving procedure for the dentist and the lab technician because it takes only 30-40 minutes for completion as compared to conventional casting technique which takes $2^1/_2$ – 3 hours for completion. No statistically significant variation in the marginal discrepancy was observed in all the four quadrants for both accelerated and conventional casting techniques. (Table I)

Conventional casting technique (Group – I) showed mean surface roughness of 2.60 µm while accelerated casting technique (Group – II) showed mean surface roughness of 2.44 µm. Comparison of surface roughness showed that there was no statistically significant difference in surface roughness between the two groups. (Table II)

IV. Discussion:

Taggart, in 1907, introduced his inlay casting technique and machine at the First District Dental Society meeting in New York City [4]. In dentistry, virtually all casting is done using some form or adaptation of the lost-wax technique. Shrinkage of wax and metal must be compensated with expansion in the investment if the casting is to have the appropriate dimensions [5]. The first published attempt to accelerate the lost wax technique with the use of phosphate-bonded investment for complete crown was made in 1988 by Marzouk and Kerby [1] who recognized the importance of investment temperature. Their study revealed no statistical circumferential difference between investment groups introduced in a 732°C preheated oven after 15 – min bench set and the conventional technique.

Campagni et al. (1993) [6] tested the fit of dowel and cores made of noble alloy by an accelerated casting technique. Blackman (2000) [7] measured marginal sharpness and diameter changes for crowns cast with type III gold alloy by using phosphate-bonded investment and rapid burnout techniques, and concluded that rapid mould preparation resulted in loss of marginal fineness. Murakami et al. (1994) [8] studied the rapid burnout technique with gypsum-bonded investment to examine surface aspects and fit of complete crowns and noted that, less expansion had occurred and was probably responsible for increased gaps.

In the present study, the whole process of investing and burnout was in accordance with Konstantoulakis et al. (1998) [2]. Konstantoulakis et al. (1998) [2] and Schilling et al. (1999) [9] reported that crowns fabricated with the accelerated casting technique were not significantly different from those fabricated with conventional technique.

The results indicate that within the limitations of the present study, the castings produced by accelerated casting technique showed the same fit as conventional casting technique with two-stage wax elimination technique in accordance with Konstantoulakis et al. (1998) [2].

The results from the surface roughness test show that the mean surface roughness of cast specimens was less than 3 µm. Statistical differences in the surface roughness were not demonstrated in specimens made with the accelerated technique as compared with the conventional technique (P>0.05). Evaluation of the SEM microphotographs revealed no apparent differences in the grain structure between the castings made with the conventional technique and those made with the accelerated technique, which was in accordance with Konstantoulakis et al. (1998) [2] and Anurag Hasti et al. (2010) [10].

Ronald Blackman (2000) [7] found crowns made with conventional schedule to have greater surface roughness as compared to accelerated schedule.

V. Limitations Of The Study-

1. In this study, only phosphate bonded investment was used, other investment materials could also have been used.
2. Only one single wax pattern crown was invested per casting ring. In order to simulate a clinical situation, investing multiple wax patterns into the same casting ring also needed to be assessed.
3. Sample size was small. A greater sample size would have helps us assessed greater variations and achieve a more definite results.
4. Only Ni-Cr ceramo-metal alloy was used. Co-Cr and Ti alloys should also be used.
5.

VI. Figures And Tables

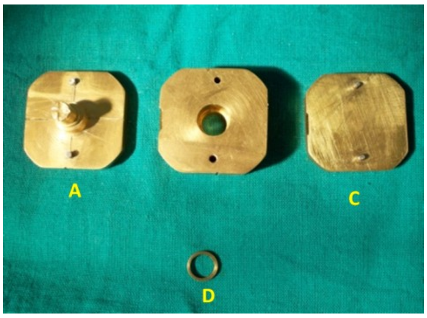

Fig.1:Parts of stainless steel die assembly used for fabrication of wax patterns. A : Die, B : former, C : base, and D : spacer.

Fig.2:Wax pattern seated on die.

Fig.3:Casted sample seated on die.

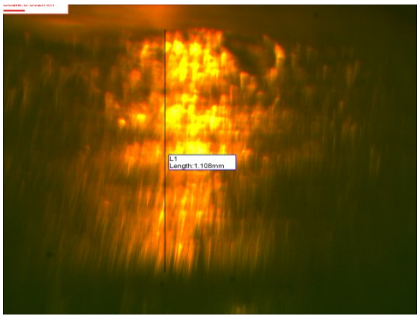

Fig.4a:Measurements between wax pattern margin and die margin.

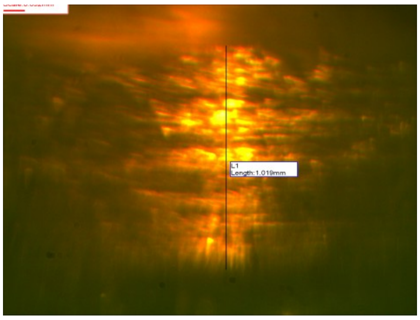

Fig.4 b:Measurements between casted crown margin and die margin.

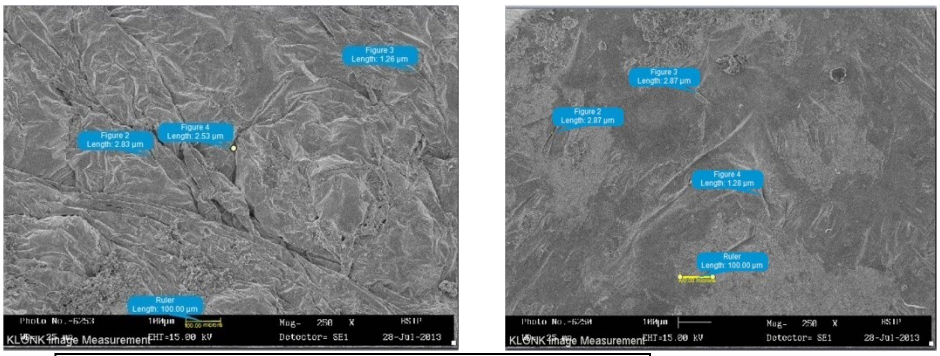

Fig.5:Measured SEM images(a) group I (b) group II

Table I: Comparison of Marginal Gap at different locations as well as average gap between two groups (mm)

Location	Group I (n=20)		Group II (n=20)		Significance of difference (Independent samples "t"-test)	
	Mean	SD	Mean	SD	"t"	p
Measurement 1	0.1632	0.0426	0.1806	0.0628	-1.028	0.310
Measurement 2	0.1574	0.0500	0.1615	0.0433	-0.277	0.783
Measurement 3	0.1412	0.0425	0.1602	0.0435	-1.398	0.170
Measurement 4	0.1553	0.0464	0.1168	0.0531	2.443	0.019
Average	0.1543	0.0201	0.1550	0.0251	-0.104	0.917

Table II: Comparison of Surface Roughness between Two groups(µm)

SN	Variable	Group I (n=30)	Group II (n=30)
1	Number of observations	30	30
2	Minimum	1.28	1.26
3	Maximum	3.43	3.30
4	Mean	2.60	2.44
5	SD	0.64	0.68
6	Median	2.88	2.65
t= 0.938; p=0.352			

VII. Conclusion:

The present invitro study was undertaken to compare the accelerated casting technique vs. the conventional casting technique vis-a-vis marginal fit and surface roughness. On the basis of the results obtained in the present study, it was concluded that marginal fit and surface roughness were comparable amongst cast Ni-Cr ceramometal alloy samples using conventional and accelerated casting techniques.

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