

# Comparison of Linear Dimensional Change, Surface Hardness and Surface Roughness of Refractory Model Prepared From Two Different Duplicating Media

Amit Porwal\*, Naveen H. Chandrashekhar\*, Ramesh K. Nadiger\*,  
Roseline D. Meshramkar\* and Satyabodh S. Guttal†

**Abstract** - The aim of this study was to evaluate and compare the linear dimensional change, surface hardness and surface roughness of the refractory casts poured against different duplicating media. Polyvinyl siloxane and Agar-agar were used for duplicating the stainless steel die. Sixty refractory models were prepared which were divided into two groups: I and II with 30 samples each respectively. Each group was subdivided into 3 subgroups with 10 samples each which were treated differently. All the specimens were measured for the linear dimensional change and surface hardness and the obtained data was statistically analyzed. Surface roughness was evaluated qualitatively taking SEM photomicrographs. Statistical analysis of linear dimensional change using one-way ANOVA showed statistically significant difference between subgroups of group I and non-significant difference between subgroups of group II. One-way ANOVA for Brinell hardness number showed statistically significant difference between the subgroups of group I & II. Student's 't' test results for linear dimensional change among different subgroups of group I & II showed significant difference between IA-IIA, IB-IIB, IC-IIC. Similarly 't'-test results for Brinell hardness number showed significant difference between subgroups IA-IIA, IB-IIB, and IC-IIC. Surface characteristics of the refractory casts poured against polyvinyl siloxane duplicating media were found to be better than the Agar media.

KEY WORDS: Cast duplication, refractory cast

## INTRODUCTION

The success of cast partial denture is dependent on various clinical and laboratory procedures and at each of these stage there is a possibility for loss of accuracy. Hence, the accuracy with which these procedures are completed is of importance in the success of the casting. Duplication of the master cast, which is one of the important procedures, has a definite disadvantage of providing an easily abradable and roughened surface of the model. This can be attributed to the larger particle size of the refractory material used in the investment<sup>1</sup>. To prevent the surface of the duplicated master model from being abraded, to preserve the duplicated details and to provide a smooth and hard surface for working; the refractory models are treated with hardeners. These hardeners get readily absorbed onto the surface of the refractory models and also seal the surface pores. Cast hardeners are therefore said to improve the surface hardness, preserve surface details and bring about better adherence and adaptability of pattern wax on the refractory models.<sup>2</sup>

Several studies have reported the physical properties and the aging characteristics of duplicating materials<sup>3,4</sup>. The relationship between duplicating materials and the dimensional changes that occur during the preparation of their refractory casts also have been described<sup>5</sup>. The

compatibility of the duplicating material with the investment may be reflected in the surface reproduction, detail, surface hardness of the refractory cast, and the effect of the duplicating material on the thermal expansion of the investment<sup>6</sup>.

Agar has been used for a number of years in the preparation of the elastic duplicating materials<sup>7,8,9</sup>, but in recent years many other duplicating material like alginate and aqueous acrylamide gel duplicating material<sup>10</sup> have been used but none of them was found to be more accurate. Another duplicating material based on polyvinyl siloxane (PVS)<sup>11</sup> has become available and is being used routinely.

Peyton and Craig<sup>7</sup> studied the compatibility of the two phosphate bonded investments with a range of duplicating materials. One investment was compatible with all the material tested, while the second investment was generally incompatible with agar type duplicating gels, which produced an unacceptably rough cast surface. The second investment produced good surface in contact with the recommended duplicating material, and both investments showed greater hardness of the surface that had set in contact with this duplicating material. However, the selection of the duplicating material may affect the accuracy of the final cast because of the differences in investment expansion of different materials<sup>12</sup>.

Jones and Wilson<sup>13</sup> showed crazing and disintegration of some phosphate bonded investments that had set in the presence of a free excess of water. The same investments also showed increased expansion in duplicating gel. Likeman *et al*<sup>14</sup> compared two phosphate bonded investments that were poured into moulds of a duplicating gel and a

\* MDS

† MDS, MFPT

polyvinyl siloxane duplicating medium and were examined for surface hardness. Brinell hardness of the samples poured in the polyvinyl siloxane was found to be greater. Cast hardeners achieved some of the re-hardening of the dried investment samples. However he (the author) found greater surface irregularity of the samples poured in duplicating gel than in poly vinyl siloxane, particularly in one investment.

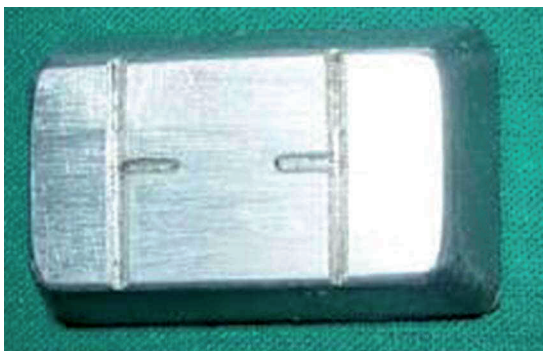
The fabrication of cast metal prosthesis by lost wax technique is in practice since 1920<sup>15</sup> and since then the use of refractory cast for making wax pattern has gained importance.

Traditionally, the refractor cast was obtained by duplication of master cast by agar gel. Lately the use of silicone has gained popularity as a duplicating material. Even though the use of silicone is very much prevalent, the literature is sparse on the change in the linear dimension of the refractory cast poured in silicone duplicating material. The present study was undertaken to evaluate and compare the surface roughness of the refractory cast and the effect of drying and surface treatment by hardening agent, on the linear dimensional change and hardness of the refractory cast poured against Polyvinyl siloxane and Agar duplicating medium.

## MATERIALS AND METHODS

A highly polished stainless steel metal die (Fig.1) which had two horizontal and vertical lines was used to determine the dimensional accuracy of the duplicating medium. The distance between the intersection of the vertical lines and the two horizontal lines of the refractory cast, poured against different duplicating media was measured with the help of Traveling Microscope. The specific dimension of the stainless steel metal die between the intersection of the horizontal and vertical lines was found to be 1.869 cm as measured under Traveling Microscope. Before duplicating, the die was ultrasonically cleaned to remove any residue and allowed to air dry.

The stainless steel metal die was placed in the duplicating flask. The processing temperature for Agar agar (Wiro-double; Bego Dental, Herbst, Germany) ranged between 45°C to 47°C. The duplication was carried out according to manufacturer's instructions in a duplicating unit (Dublitherm; Degussa, Germany) which monitored the temperature control. At this temperature, the material was poured into the flask and kept aside for gelation. A new



**Figure 1.** Standard metal die used for duplication.

mould was prepared for each sample.

For Silicone mould preparation, the metal die was placed in the flask and was sealed. The material (Wirosil; Bego) was taken in a mixing jar in the ratio of 1:1, and was mixed until the mixture turned uniform light blue in color. Duplication mould was filled on the vibrator and was removed immediately to avoid air entrapment.

Refractory investment (Wirovest; Bego) material was vacuum mixed and the cast poured according to the manufacturers instructions for both the gel and silicone moulds. The samples obtained from both the duplicating media were divided into two groups. Group I: refractory cast poured in silicone duplicating medium and Group II: refractory cast poured in agar duplicating medium. Each Group consisted of 30 samples which were further divided into three Subgroups 10 samples each. Among the subgroups, one of them was subjected to hardening (Durol; Bego) treatment as follows:

Subgroup IA - specimens measured as set in room temperature.

Subgroup IB - specimens measured after drying of the refractory cast according to the manufacturer's instructions.

Subgroup IC - specimens measured after hardening.

Subgroup IIA - specimens measured as set in room temperature.

Subgroup IIB - specimens measured after drying of the refractory cast according to the manufacturer's instructions.

Subgroup IIC - specimens measured after hardening.

Refractory casts obtained from both the moulds were observed under Traveling Microscope to the nearest of 0.01mm at x50 magnification on each refractory cast. The distance between the intersection of the vertical line and the two horizontal lines of the refractory cast poured against different duplicating medium was measured and the difference in linear dimension was noted. All readings were done from perpendicular line of view. At least three readings were taken for each sample to minimize human error in recording the values and the mean was calculated. Similarly, the linear dimension change for all the samples of the subdivision (A, B, C) of Group I and Group II were measured.

Brinell hardness testing machine (Saroj Hardness Testing Machine, Model: Sn 6293; Mumbai, India.) which could apply a load ranging from 588.4 N to 2451.7N, with a carbide or steel ball with diameters of 2.5, 5 and 10mm was used for testing surface hardness. The specimens were tested using a 5mm steel ball indenter, under a load of 980.7 N. The full load was applied for 10 to 15 seconds and then removed. Some of the softer specimens that fractured under the test were replaced with new samples. The diameter of the indentation left in the test material was measured in at-least three places - usually at right angles to each other and were averaged ( $D_i$ ). These measurements were done with the help of Brinell Microscope. The Brinell hardness numbers ( $\text{kg/mm}^2$ ) of all the specimens in all the Groups were calculated and the obtained values were subjected to statistical analysis using one way Anova and student's 't' test.

**Table 1.** Mean and standard deviation of the linear dimensional change (in mm) of test specimens of various subgroups of group I and group II

SUBGROUPS	IA	IB	IC	IIA	IIB	IIC
Mean	$3.7 \times 10^{-4}$	$2.9 \times 10^{-4}$	$2.4 \times 10^{-4}$	$9 \times 10^{-4}$	$8.9 \times 10^{-4}$	$8.2 \times 10^{-4}$
S.D.	$.48 \times 10^{-4}$	$.74 \times 10^{-4}$	$.52 \times 10^{-4}$	$.67 \times 10^{-4}$	$.88 \times 10^{-4}$	$1.14 \times 10^{-4}$

**Table 2.** Statistical comparison (one way anova) of the linear dimensional change of test specimens of various subgroups of group I and group II

Source of Variation	GROUP I				GROUP II			
	DF	F-value	P-value	Significance	DF	F-value	P-value	Significance
Between Subgroups	2	12.35	0.0002	S	2	2.28	0.1216	NS
Within Subgroups	27				27			
Total	29				29			

A cingulum ledge was prepared on an extracted central incisor tooth by milling machine. The prepared tooth was duplicated in both the duplicating medium and the refractory casts were obtained. The specimen's surface roughness was qualitatively evaluated with Scanning Electron Microscope. Specimens were sputter coated with gold before observation under SEM to make surface electrically conductible as well as to increase the contrast on the surface profile. Then photomicrographs were made with SEM at X30 and X60 magnifications. Actual surface roughness was determined by the height of the convexities and the depth of concavities obtained from photomicrographs of the sections.

## RESULTS

Table 1 showed the mean and standard deviation of the linear dimensional change of the test specimens. Table 2 shows the statistical comparison of the mean linear dimensional change of various subgroups of groups I and II using the one-way ANOVA test. The results showed statistically significant difference between the subgroups of group I ( $F=12.35$ ,  $p=0.0002$ ) and II ( $F=2.28$ ,  $p=0.12$ ). Table-3 demonstrates the results of student's t-test of the linear dimensional change between the subgroups of group I and group II. Significant differences were found between the subgroups IA-IC ( $t=5.81$ ,  $p=0.00$ ) and IA-IB ( $t=2.87$ ,  $p=0.01$ ). There was no significant difference found at 5% level among the groups IB-IC ( $t=1.76$ ,  $p=0.09$ ), IIA-IIB ( $t=0.29$ ,  $p=0.77$ ), IIA-IIC ( $t=1.92$ ,  $p=0.07$ ) and IIB-IIC ( $t=1.54$ ,  $p=0.14$ ). Subgroups IA showed highest linear dimensional change than subgroups IB and IC. Table 4 depicts the results of student's t-test for mean linear dimensional change values between different subgroups of groups I and II. Significant difference was found among the subgroups IA-IIA, IB-IIB and IC-IIC with ( $t=20.36$ ,  $p=0.00$ ), ( $t=-16.57$ ,  $p=0.00$ ) and ( $t=-14.71$ ,  $p=0.00$ ) respectively at 1% level of confidence. It implies that the specimens poured in agar duplicating medium showed significant difference in linear dimensional change ( $p<0.001$ ) than specimens poured in silicone material.

**Table 3.** Statistical comparison (student's t-test) of the linear dimensional change of test specimens of various subgroups of group I and group II

SUBGROUPS <i>n=10</i>	t	P-value	Significance
IA IB	2.87	0.0102	S
IA IC	5.81	>0.0001	S
IB IC	1.76	0.0962	NS
IIA IIB	0.29	0.777	NS
IIA IIC	1.9215	0.0706	NS
IIB IIC	1.54	0.1400	NS

Table 5 reveals the mean and standard deviation of Brinell hardness number of the test specimens of IA, IB, IC, IIA, IIB and IIC subgroups. The highest Brinell hardness number was that of subgroup IC ( $29.4 \pm 1.0$ ), followed by subgroup IB ( $25.4 \pm 0.9$ ) and the least Brinell hardness number was that of subgroup IA ( $18.0 \pm 0.9$ ). Similarly, for group II highest was for subgroup IIC ( $27.9 \pm 0.6$ ), followed by subgroup IIB ( $18.7 \pm 0.9$ ) and the least Brinell hardness number was for subgroup IIA ( $16.2 \pm 0.8$ ). The value of Brinell hardness number increased following treatment with heat and hardening agent. Table 6 shows the statistical comparison of the mean Brinell hardness number of IA, IB and IC and IIA, IIB and IIC using the one-way ANOVA test. The results showed statistically significant difference between the subgroups of group I ( $F=377.56$ ,  $p=0.00$ ) and group II ( $F=642.87$ ,  $p=0.00$ ).

**Table 4.** Statistical comparison (student's t-test) of the linear dimensional change (in mm) of test specimens of group I and group II

SUBGROUP	GROUP I		GROUP II		t	P-value	Significance
	Mean	S.D.	Mean	S.D.			
A	3.7 x 10 <sup>-4</sup>	.48 x 10 <sup>-4</sup>	9 x 10 <sup>-4</sup>	.66 x10 <sup>-4</sup>	20.36	>0.0001	S
B	2.9 x 10 <sup>-4</sup>	.74 x 10 <sup>-4</sup>	8.9 x 10 <sup>-4</sup>	.87 x 10 <sup>-4</sup>	16.57	>0.0001	S
C	2.4 x 10 <sup>-4</sup>	.52 x 10 <sup>-4</sup>	8.2 x 10 <sup>-4</sup>	1.3 x 10 <sup>-4</sup>	14.71	>0.0001	S

**Table 5.** Mean and standard deviation of Brinell hardness number (kg/mm<sup>2</sup>) of the test specimens of various subgroups of group I and group II

SUBGROUPS	IA	IB	IC	IIA	IIB	IIC
MEAN	18.0	25.4	29.4	16.2	18.7	27.9
S.D.	0.9	0.9	1.0	0.8	0.9	0.6

**Table 6.** Statistical comparison (one way anova) of Brinell hardness number of the test specimens of various subgroups of group I and group II

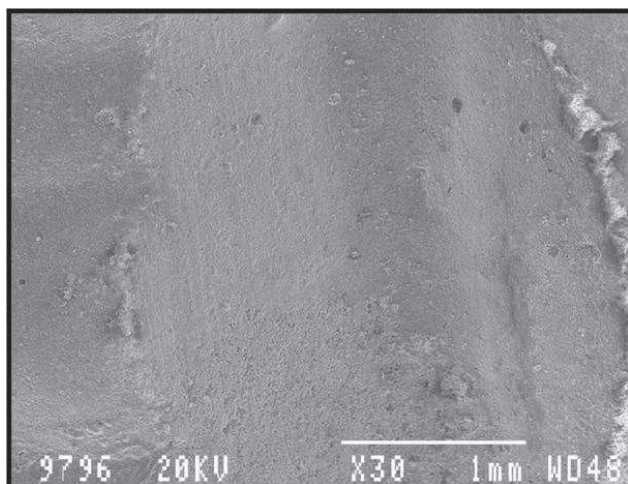
Source of Variation	GROUP I				GROUP II			
	DF	F-value	P-value	Significance	DF	F-value	P-value	Significance
Between Subgroups	2	377.56	>0.0001	S	2	642.87	>0.0001	S
Within Subgroups	27				27			
Total	29				29			

**Table 7.** Statistical comparison (student's t-test) of Brinell hardness number of the test specimens of various subgroups of group I and group II

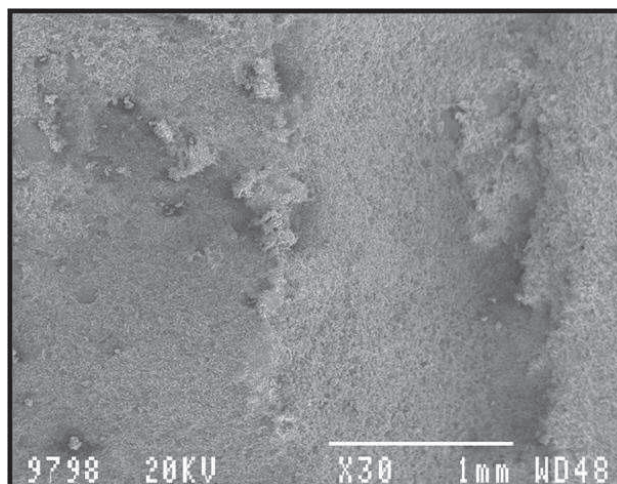
SUBGROUPS n=10	t	P-value	Significance
IA IB	18.32	0.0000	S
IA IC	26.29	0.0000	S
IB IC	9.27	0.0000	S
IIA IIB	6.77	0.0000	S
IIA IIC	36.69	0.0000	S
IIB IIC	27.47	0.0000	S

**Table 8.** Statistical comparison (student's t-test) of Brinell hardness number (kg/mm<sup>2</sup>) of the test specimens of various subgroups of group I and group II

SUBGROUP	GROUP I		GROUP II		t	P-value	Significance
	Mean	S.D.	Mean	S.D.			
A	18.0	0.9	16.2	0.8	4.4554	0.0003	S
B	25.4	0.9	18.7	0.9	17.1427	0.0000	S
C	29.4	1.0	27.9	0.6	4.06	0.0007	S



**Figure 2.** SEM photomicrograph of cast poured in silicone duplicating material.



**Figure 3.** SEM photomicrograph of cast poured in Agar duplicating material

Student's t-test for Brinell hardness between subgroups IA, IB, IC, IIA, IIB and IIC are displayed in Table 7. Further, table 8 shows the results of student's t-test for mean Brinell hardness number between subgroups of I and II. The SEM qualitative analysis of the surface of the specimens showed less roughness on the cingulum ledge duplicated with silicone than the agar mold (Fig 2 & 3)

## DISCUSSION

The ultimate success of any removable metallic prosthesis is attributed to the duplicated casts which are accurately reproduced from the master cast<sup>16,17</sup>. An accurate refractory cast may be obtained when an impression of the original cast is made in an elastic material and poured with an investment. The resultant cast should be resistant to surface abrasion during various laboratory steps such as wax up or during removal of the wax pattern for casting. Several investigators<sup>18,19</sup> have studied the linear dimensional change of impression materials and die stones but the literature revealed less record on the linear dimensional change of refractory cast, poured against two duplicating media before and after drying and hardening treatment.

Dootz *et al*<sup>12</sup> concluded that the selection of duplicating material may affect the accuracy of the final cast because of the differences in investment expansion of different materials.

In the present study, the linear dimensional change was found to be less with refractory cast poured against silicone duplicating material. This may be attributed to the absence of volatile reaction products such as water and alcohol<sup>1</sup>. The resultant increase in the linear dimension of the refractory cast poured against agar duplicating material may be due to the greater proportion of water content, presence of syneresis property, number of reboiling cycles and delay in pouring<sup>16</sup>. Within the subgroups of group I, there was a change in linear dimension. Samples treated with hardener and heat treatment showed reduced linear dimensional change. This could be due to the continuous setting expansion of the phosphate bonded investment material. This is in accordance with the study conducted by

Stevens<sup>20</sup> on the effect of early heating on the expansion of phosphate bonded investment material. However, the hardener and the heat treatment did not have any statistical significance on linear dimension for the casts poured with agar. This may be because of the crazing of the surface of investments in the presence of a free excess of water from hygroscopic expansion<sup>13</sup>.

The treated refractory casts exhibited better surface hardness than untreated refractory casts of the subgroups of both groups. This may be because the hardener would seal the interstitial pores on the surface and harden the model. However, the surface hardener values were found to be better with group 1 than group 2. This was in agreement with Likeman *et al*<sup>14</sup> who observed that, the investment poured in silicone duplicating material was harder and denser than the same investment poured in agar. They also observed that a trace of investment was found clinging to the surface of gel that was associated with the degradation of the surface of the cast which was poured with agar.

The roughness of the investment poured in duplicating material inevitably affects the surface detail of the cast. In the areas of a sharp line or ridge the casts are more vulnerable to detail loss resulting in a poorly fitting framework. The surface of the refractory cast poured in silicone duplicating material had an even and uniform surface texture with less exposure of the refractory particles. SEM photomicrograph of the refractory cast poured in agar had the roughened and irregular surface. Whereas the casts obtained from silicone mold had a uniform surface texture and less exposure of the refractory particles.

## CONCLUSION

Within the limitations of the study, silicon duplicating material exhibited less linear dimensional change, increased surface hardness and less surface roughness of the refractory casts compared to the casts duplicated from the agar material.

## REFERENCES

1. Anusavice KJ. Phillips Science of Dental Materials, 10th Edition, Saunders
2. Bates John F. Removable partial denture construction 2nd edition
3. Craig RG, Peyton FA. Physical Properties of Elastic Duplicating Materials. *J Dent Res* 1960; **39**:391-404
4. Craig RG, Gehring PE, Peyton FA. Aging characteristics of elastic duplicating compounds. *J Dent Res* 1962; **41**:196-206.
5. Craig RG, Anthony DH, Peyton FA. Dimensional changes in duplicated investment casts. *D. Progr.* **2**:35, 1961
6. Earnshaw R. Investments for casting cobalt chromium alloys, *Br Dent J* 1960; **108**: 389-396.
7. Peyton FA, Craig RG. Compatibility of duplicating compounds and casting investments. *J Prosthet Dent* 1962; **12**:1111-1124.
8. Phillips R, Ito BY. Factors affecting the surface of stone die poured in hydrocolloid impressions. *J Prosthet Dent* 1952; **2**:390-400.
9. Williams EO, Hartman GE. Compatibility of reversible hydrocolloid duplicating materials and dental stone. *J Prosthet Dent* 1984; **52**:699-703.
10. Dootz ER, Craig RG, Peyton FA. Aqueous acrylamide gel duplicating material. *J Prosthet Dent* 1967; **17**:570-577.
11. George W. Barnhart. Silicone Rubber as a Laboratory Duplicating Material. *J Prosthet Dent* 1961; **15**:1124.
12. Dootz ER, Craig RG, Peyton FA. Influence of investment and duplicating procedures on the accuracy of partial denture castings. *J Prosthet Dent* 1965; **15**: 679-690.
13. Jones DW, Wilson HJ. Setting and hygroscopic expansion of investments. *Br Dent J* 1970; **129**: 22-26.
14. Likeman PR, Radford DR, Andrez SJ. The surface of investments poured against different duplicating media. *Int J Prosthodont* 1996; **9**:572-579.
15. Miller E, Grasso JE. Removable partial Prosthodontics. II edition CBS Publisher and distributor 1988, pp 336-337.
16. Craig RG. Restorative dental materials. 8<sup>th</sup> edition st Louis; CV MOSBY, 1989; pg 307-308.
17. Williams EO, Hartman GE. Compatibility of reversible hydrocolloid duplicating materials and dental stones. *J Prosthet Dent* 1984; **52**:699-703.
18. Marcinak CF, Draughn RA. Linear dimensional changes in addition curing silicone impression materials. *J Prosthet Dent* 1982; **47**:411-413
19. Rajapus P, Rosemarie J, Charles G, Carlos MA, Keith M. Hydrophilic polyvinyl siloxanes impression materials- Dimensional accuracy, wettability and effect on gypsum hardness. *Int J Prosthodont* 1991; **4**:240-248.
20. Stevens L. The effect of early heating on the expansion of phosphate bonded investment material. *Aust Dent J* 1983; **28**:366-369

## ADDRESS FOR CORRESPONDENCE

Dr Satyabodh S Guttal, Professor, Dept of Prosthodontics, SDM College of Dental Sciences, Sattur, Dharwad 580 009, Karnataka, India. E-mail drsatyabodh@yahoo.co.in