

# A Comparison of the Accuracy of Three Removable Die Systems and Two Die Materials

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**Abstract** - The purpose of this study was to evaluate the dimensional shift of three commonly used die systems (Conventional system, Pindex system, Di-Lok tray system) with two commercially available type IV die stones (Ultra rock and Pearl stone). Under controlled conditions, ten casts, each with two removable dies, were constructed for each system for a total of 30 casts and 60 removable dies. Before and after sectioning measurements to within 0.01 mm in horizontal and vertical planes were recorded and differences calculated. Data were analyzed with 't' tests, one way analysis of variance and post hoc Tukey test. The results demonstrated that among the die systems compared, no single system was superior to the others in all respects. But among the die materials, dies poured in Pearl stone exhibited more dimensional changes than Ultra rock ( $p < 0.05$ ). Selection of die material is as critical as selection of any particular die system for successful fabrication of fixed partial denture and implant prosthesis

KEY WORDS: Removable die, Pindex system, Di-Lok tray system, Ultra rock, Pearl stone

## INTRODUCTION

The successful construction of long span fixed partial dentures and implant prosthesis depends on the accurate fabrication of the removable die. The removable die technique requires an accurate reproduction of the prepared tooth, the surrounding soft tissues, the adjacent and the opposing teeth. The die system captures this necessary information so that it can be transferred to the laboratory for fabrication of wax pattern. Precise relocation of the die in the master cast is critical to the system's success<sup>1</sup>. Several authors<sup>1-4</sup> have indicated desirable characteristics for the removable dies and the die system as follows: stability and accuracy must be inherent in the die system used; the dies should be made of hard dense material; should seat in the master cast accurately, positively, and solidly; provide exact relationships between the prepared teeth and the adjacent and opposing teeth. Any deviation from these characteristics, especially the hardness of the die material and the specific removable die system will affect replacement accuracy and may create measurable shift in die position. This measurable shift can affect the relationship between the prepared teeth to the adjacent and the opposing teeth. So, the final restoration fabricated from these dies does not only have poor internal fit but imperfect external contours as well. Hence it is critical to select the appropriate die system and die material and adopting meticulous application of the procedures to minimize the measurable shift.

Various techniques have been reported in the literature such as Conventional system, Pindex system, Di-Lok tray system, DVA system, Zeiser model system, etc for the construction of a working cast and removable dies that can be

assembled in the correct relationship<sup>5-8</sup>. Each system has its own merits and demerits; selection of a particular system depends on the abilities of the operator and the availability of special equipment needed for the construction of the dies. Few scientific investigations can be found in the literature to support any one particular method. Various die materials are available for construction of the dies namely the type IV and type V gypsum die stones, epoxy resins, flexible dies materials (Impregum F die material), etc. The two critical characteristics of cast-and-die materials, dimensional accuracy and resistance to abrasion while the wax pattern is being formed, are adequately achieved with type IV die stone. The inherent setting expansion of the gypsum die material affects the reproduction of the original tooth position in the working cast. It is important to control the progressive setting expansion of the die stone in the fabrication of removable dies, as it undergoes continuous isotropic expansion<sup>9</sup>. The maximum expansion of die stone occurs approximately after 2 hours from the start of the mix and the value progressively increases in the following 24 hours<sup>10,11</sup>. Only one study has shown that casts made from type IV dental stone distorts but that significant differences existed from various brands<sup>4</sup>. The physical characteristics and the quality of the type IV die stone from different manufacturers, the nature of different die systems warrants further investigation. The purpose of this investigation was to evaluate the dimensional shift of three commonly used die systems with two commercially available type IV die stones.

## MATERIALS AND METHODS

From a dentoforn dentulous model, the right upper second premolar and second molar were prepared to receive restoration with first molar as an edentulous area. A total of thirty impressions of the simulated three unit fixed partial denture were made with silicone impression material. The impression making could be elaborated as follows; tray

\* MDS

adhesive material was uniformly painted over the impression tray and was allowed to dry completely for 5 minutes. Equal proportions of the base and catalyst paste of the putty material were hand mixed homogeneously and loaded onto the impression tray. A thin polyethylene sheet was used as a spacer to provide space for light body impression material. The impression of the dentulous model with the prepared teeth and edentulous area was made. The spacer was removed; equal lengths of base and catalyst paste of the light body material were dispensed onto the glass slab and mixed for 45 seconds to obtain a homogenous mix. Then, the light body material was loaded over the putty material and the impression was made. Ten working casts, five poured in Ultra rock die material and five poured in Pearl stone die material for each of the three systems namely Conventional system, Pindex system and, Di-Lok tray system were made from thirty impressions. The water to powder ratio for Ultra rock and Pearl stone was 0.20 and 0.25 respectively, according to the manufacturer. The three die systems namely Conventional system, Pindex system, and Di-Lok system were named as group A, group B, and group C respectively and the die materials namely Ultra rock and Pearl stone as subgroup a and subgroup b, respectively.

#### Fabrication of casts from Conventional system

Three bi-pins were attached to the hair pins with low viscosity cyanoacrylate cement and positioned over the center of the prepared teeth and edentulous area on the impression. Two additional pins were placed; one in the anterior region and the other in the posterior region on the other side of the arch for stability. The die stone was weighed on the physical balance in gram-scale measure and mixed with distilled water according to the manufacturer's recommended water to powder ratio and hand mixed in a vacuum mixer bowl until the powder was wetted. Then the mix was mechanically spatulated with a vacuum of -60 cm of mercury at 400 rpm to draw out air bubbles from the slurry mix. The mixed stone was gently vibrated and poured into the impression using the model vibrator. The impression was poured with a two pour technique; the first pour was made after positioning the bi-pins over the impression. After the initial set the hair pins were removed. After the final set ( $12 \pm 4$  min), the cast was retrieved from the impression. Any excess material is trimmed with model trimmer. The metal sleeves were attached to the bi-pins. The underside of the cast was lubricated with petrolatum and the base was poured in type III dental stone on the base former.

#### Fabrication of casts from Pindex system

The cast was poured in die stone (first pour) according to the manufacturer's recommendation as outlined above for conventional system. After about one hour, the base of the first pour was trimmed absolutely flat in the model trimmer. The cast was placed on the drill table and oriented until the light beam in the drill unit was directed to the desired point on the occlusal surface of the proposed die. The light beam and the drill were aligned in the unit. The operation of the drill mechanism produced holes in the underside of the cast corresponding to the placement of the light beam. The cast was reoriented and five holes

were placed. Then, five standard bi-pins were cemented in specially drilled holes using cyanoacrylate cement and the metal sleeves were attached to the bi-pins. The underside of the cast was lubricated with petrolatum and the base was poured with type III dental stone.

#### Fabrication of casts from Di-Lok system

The Di-Lok system consists of a plastic mold into which the appropriately trimmed cast is fitted and stabilized. The full arch Di-Lok tray as used in this investigation can be disassembled into three pieces: the body of the tray which establishes the arch curvature, the outer tray perimeter which confines the poured base to this curvature, a posterior locking bar which stabilizes the assembly as a unit. The first two pieces are ribbed so that when the base is poured to lock the cast in position, the entire cast base assembly has stability and accuracy during reassembling. The cast was poured in die stone according to the manufacturers' instruction as outlined above for conventional system. The same die stone (type IV) is used to fill the Di-Lok tray. The impression tray was placed into the Di-Lok tray when the stone is still wet. After the final set of the die material, the impression and the Di-Lok tray were removed from the cast.

A total of 30 casts consisting of 60 dies from the three systems were studied in this investigation. Four reference points (A,B,C,D) were marked on each cast with permanent marker for vertical and horizontal measurements (Figure 1). For vertical height measurement, point (A) was marked approximately 2mm from the gingival margin in the centre of the die; point (B) was marked on the center of the base on the same line. The distance A-B gave the vertical measurement of that particular die. For horizontal measurement, point (C) was marked on the left side of the prepared tooth on the same line where point (A) was marked; and point (D) was marked on the right side of the prepared tooth. The points (C), (A) and (D) were on the same line. The distance A-D gave the horizontal right side measurement. The distance A-C gave horizontal left side measurement. The measurements were carried out by using a traveling microscope before sectioning the die. Such before-sectioning measurements were done for all the systems. All measurements were obtained to within 0.001 cm. Each point was measured three times in horizontal and vertical planes to produce a base line data. A total of 180 measurements were made before sectioning the dies. After about 24 hours, the casts were sectioned by using hand saw to produce 60 removable dies which were then removed and repositioned 30 times to simulate laboratory

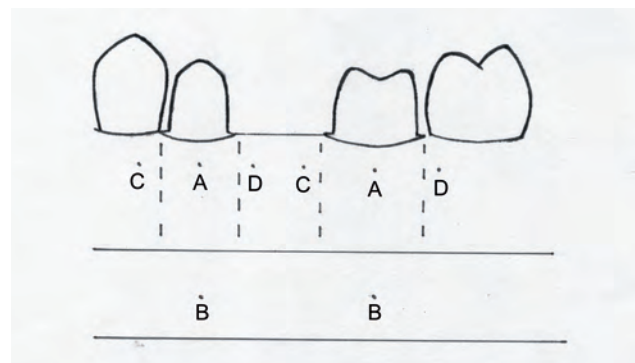


Figure 1. Schematic drawing of cast and die assembly and reference points

usage. The dies and casts were cleaned with a soft brush and compressed air before they were repositioned for measurements. The after sectioning measurements were made at the same reference points, giving a total of 360 measurements. In each instance the differences between before and after removals were measured, and the mean vertical and horizontal shifts were calculated.

### Statistics

Standard descriptive statistical calculations were computed for each system. To determine dimensional changes from sectioning of dies and to compare differences between the two die materials (in each die system), paired and unpaired 't' tests were performed, respectively. One way analysis of variance (ANOVA) was used for multiple group comparison and it was conducted for each measurement AC, AD, and AB to test the difference in landmark distances on the cast at before sectioning and then at after sectioning using three different systems with two different die materials. When there was a significant effect ( $p < 0.05$ ), the Tukey post hoc was used to test for pair wise comparison of means.

### RESULTS

Statistical comparison of before and after sectioning measurements in horizontal and vertical dimensions with Conventional system, Pindex system and Di-Lok tray system are noted in Table 1, Table 2, and Table 3 respectively. The mean vertical height measurement (AB) for before sectioning and after sectioning of Ultra rock die in Conventional system was  $1.21 \pm 0.22$  cm and  $1.30 \pm 0.21$  cm respectively. Similarly it was  $1.28 \pm 0.13$  cm and  $1.41 \pm 0.23$  cm for Pearl stone die material (Table 1). The mean horizontal distance measurement (AD) for before sectioning and after sectioning of Ultra rock die in Pindex system was  $0.89 \pm 0.11$  cm and  $0.98 \pm 0.17$  cm respectively and Pearl stone recorded mean measurements of  $0.83 \pm 0.13$  cm and  $0.81 \pm 0.14$  cm respectively (Table 2). In Di-Lok system, the mean vertical height measurement for before sectioning and after sectioning of Ultra rock die was  $1.15 \pm 0.09$  cm and  $1.23 \pm 0.08$  cm respectively (Table 3). All the above values were statistically significant.

The results of the paired 't' test showed a significant difference in all three landmark measurements on the Conventional and Di-Lok system casts before and after sectioning of the working dies for the Pearl stone die material. There was a significant difference in AD landmark measurements in the Pindex system for Ultra rock material. Both Conventional and Di-Lok system showed significant differences in AB landmark measurements for Ultra rock die material and Pearl stone. Intergroup comparison of the two die materials showed a significant difference in the scores for AC landmark in Conventional system ( $t = 2.78$ ,  $p = 0.013$ ). Similar results were seen in Pindex system for AD landmark ( $t = 2.8$ ,  $p = 0.012$ ). These results suggest that the type of die material does have an effect on the horizontal shift for Conventional and Pindex systems. There was no statistically significant difference in vertical dimension if the mean scores of both the die materials were compared in a particular die system, but the absolute means of individual die material in Conventional and Di-Lok system were significant. The results of the one way analysis of

variance to test for difference among three die systems of one particular die material is elaborated as follows (Table 4). Preference for Pearl stone differed significantly across all the three die systems in AC landmark measurement ( $F = 3.91$ ,  $p = 0.03$ ). Similar significance was seen in AD landmark measurement also ( $F = 3.52$ ,  $p = 0.04$ ). Tukey post hoc comparison of three systems indicates that the Di-Lok system when used with pearl stone showed significant changes in horizontal measurement.

### DISCUSSION

For a satisfactory long span fixed prosthesis or implant prosthesis, the die system and the die material used in the removable die technique must meet specific requirements. They should be dimensionally stable and they should exhibit a certain degree of long term accuracy. The results of the present study demonstrated that among the die systems compared, no single system was superior to the others in all respects. But among the die materials, dies poured in Pearl stone exhibited more dimensional changes than Ultra rock.

All three die systems provided a similar degree of dimensional accuracy, although Pindex showed the least vertical movement. The dimensional shift might result from debris at the interface between the first and second pour, frictional wear of dies and/or their supporting base during 30times removal/ replacement, position of the dowel pin and progressive expansion of the die stone. According to various studies, Pindex is claimed to be more precise and ideal method for fabricating removable dies<sup>2,6,8,12,13</sup>. The cast and the die preparation and reassembly of the working cast were less complicated in Pindex system. Aramouni reported that solid casts distorted less than the Pindex system<sup>7</sup>. This is in contrast to our results where the accuracy of the conventional system is slightly inferior to Pindex.

In conventional system positioning the dowel pin over the impression is a critical factor as reported by previous studies<sup>5,7,8</sup>. A slight error in the angulations can make the die sectioning difficult. In the present study, the Di-Lok tray system exhibited more discrepancy than the Pindex. This finding is supported by Miranda et al study which indicated small inconsistent horizontal deviations and consistent vertical deviations for both systems, but the Pindex system deviations were slightly less than those of the Di-Lok system<sup>2</sup>. In Pindex system, the sectioning of the dies from the underside of the cast with a handsaw was definitely much easier than sectioning through the interproximal areas as recommended by the Di-Lok system. It is well known that gypsum products exhibit a range of linear expansion of approximately 0.04% to 0.3% after setting<sup>14</sup>. The expansion of stone has been attributed to the growth and development of the crystalline hemihydrates lattice from the supersaturated solution and the accompanying out thrust of the gypsum crystals during setting. It has been said the energy of crystallization of dental stones leaves residual stresses in the set mass. The release of such forces, however small, may affect the replacement of divided segments of casts<sup>15</sup>. This can greatly influence the accuracy of the cast/die<sup>11</sup>.

Results of the intra group comparison indicate that the type of die material does have an effect on the horizontal shift

**Table 1.** Comparison of before and after sectioning measurements with Conventional system

Measurements (cm)	Group A/subgroup a <sup>*</sup>						Group A/subgroup b <sup>*</sup>						a vs b <sup>**</sup>			
	before		after		difference	t	p	before		after		difference	t	p	t	p
	Mean	SD	Mean	SD				Mean	SD	Mean	SD					
AC	0.72	0.14	0.68	0.16	-0.04±0.10	1.33	0.22	0.70	0.17	0.79	0.10	0.08±0.10	2.59	<b>0.03</b>	2.78	<b>0.01</b>
AD	0.83	0.05	0.89	0.11	0.07±0.11	1.83	0.10	0.90	0.21	0.92	0.27	0.03±0.08	1.06	0.32	0.91	0.38
AB	1.21	0.22	1.30	0.21	0.09±0.12	2.19	<b>0.05</b>	1.28	0.13	1.41	0.23	0.14±0.17	2.55	<b>0.03</b>	0.77	0.45

\* Paired 't' test  
 \*\*Unpaired 't' test  
 p < 0.05 denotes significance

**Table 2.** Comparison of before and after sectioning measurements with Pindex system

Measurements (cm)	Group B/subgroup a <sup>*</sup>						Group B/subgroup b <sup>*</sup>						a vs b <sup>**</sup>			
	before		after		difference	t	p	before		after		difference	t	p	t	p
	Mean	SD	Mean	SD				Mean	SD	Mean	SD					
AC	0.80	0.15	0.79	0.18	-0.01±0.08	0.58	0.57	0.96	0.35	0.10	0.38	0.03±0.05	1.80	0.11	1.49	0.16
AD	0.89	0.11	0.98	0.17	0.09±0.10	2.86	<b>0.02</b>	0.83	0.13	0.81	0.14	-0.02±0.07	0.81	0.44	2.80	<b>0.01</b>
AB	1.85	0.18	1.79	0.38	-0.06±0.33	0.57	0.58	1.52	0.17	1.57	0.08	0.06±0.17	1.02	0.33	0.97	0.35

\* Paired 't' test  
 \*\*Unpaired 't' test  
 p < 0.05 denotes significance

**Table 3.** Comparison of before and after sectioning measurements with Di-Lok tray system

Measurements (cm)	Group C/subgroup a <sup>*</sup>						Group C/subgroup b <sup>*</sup>						a vs b <sup>**</sup>			
	before		after		difference	t	p	before		after		difference	t	p	t	p
	Mean	SD	Mean	SD				Mean	SD	Mean	SD					
AC	0.73	0.11	0.74	0.10	0.01±0.03	0.87	0.41	0.71	0.06	0.70	0.05	-0.01±0.05	0.46	0.66	0.84	0.41
AD	0.83	0.11	0.85	0.10	0.01±0.04	1.08	0.31	0.78	0.19	0.86	0.21	0.08±0.09	2.69	<b>0.03</b>	2.04	0.06
AB	1.15	0.09	1.23	0.08	0.08±0.03	8.02	<b>0.001</b>	1.18	0.07	1.34	0.17	0.16±0.18	2.76	<b>0.02</b>	1.30	0.23

\* Paired 't' test  
 \*\*Unpaired 't' test  
 p < 0.05 denotes significance

**Table 4.** One way analysis of variance between 3 die systems (A,B,C) and 2 die materials (a,b)

Measurements	Die material	F	p	A vs B <sup>*</sup>	A vs C <sup>*</sup>	B vs C <sup>*</sup>
AC	a	1.13	0.34	0.70	0.31	0.77
	b	3.91	<b>0.03</b>	0.25	<b>0.02</b>	0.49
AD	a	1.85	0.18	0.84	0.40	0.17
	b	3.52	<b>0.04</b>	0.44	0.35	<b>0.03</b>
AB	a	1.64	0.21	0.27	0.99	0.28
	b	1.00	0.38	0.56	0.95	0.38

\* post-hoc tukey test  
 p < 0.05 denotes significance

for Conventional and Pindex systems. Millstein PL study also indicated that all casts distort, but that significant differences exist between various brands of die stone<sup>4</sup>. In the present study dies made with pearl stone differed significantly across all the three die systems in horizontal landmark measurement. According to the manufacturer, the setting expansion for pearl stone is 0.15% as compared to 0.08% expansion for ultra rock material. This could be the reason for the pearl stone to exhibit greater expansion in all the three systems. Di-Lok tray system was less accurate than Pindex and Conventional system when Pearl stone die material was used. The inaccuracies can be related to greater expansion of die stone material since the base is also constructed with same die material in Di-Lok tray. It has been reported that adding type IV die stone as a base has shown higher expansion than type III dental stone<sup>16</sup>.

Although these data indicate movements in described planes, there is also probable slight rotational movement of dies which were not measured. The quality of restoration fit could be enhanced through use of the most desirable fabrication technique for the cast or die and selection of a stone that exhibits long term stability and minimal expansion. Material selection depends on an analysis of the properties believed to be the most pertinent to the specific use of the die. A stable, low expansion master cast material would be advantageous for multiunit implant prosthesis fabrication. Expansion test results should help determine the limitations of each material and thus make it possible to choose more intelligently the best materials, or combination of materials, for a particular use. Further studies could focus on this issue along with discrepancy estimation.

## CONCLUSION

The following conclusions were drawn from the results of this study:

In the vertical dimension, the Pindex system with either Ultra rock or Pearl stone yielded the greatest accuracy.

Significant difference existed between the systems in the horizontal dimension for the Pearl stone. Although, ANOVA did not show any significant difference between the systems with Ultra rock, the mean difference between before sectioning and after sectioning values was slightly high for any system.

Di-Lok tray system exhibited more discrepancy than Conventional and Pindex systems when Pearl stone was used.

Selection of die material is as critical as selection of any particular die system for successful fabrication of fixed partial denture and implant prosthesis

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## MANUFACTURERS' DETAILS

- Addition silicone, Elite HD; Zhermack, Rovigo, Italy
- Ultra rock, Kalabhai Karson Pvt Ltd, Mumbai, India
- Pearl stone, Asia Chemicals Ltd, New Delhi, India
- Pindex system, Coltene/Whaledent, Inc: Mahwah, N.J.
- Di- lok tray, Di-Equi Dental Products: Wappingers Falls, N.Y.
- Super Glue, Loctite, Cleveland, OH
- Type III dental stone, Kalstone: Kalabhai Karson Pvt Ltd, Mumbai, India

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## REFERENCES

1. Working casts and dies. In Rosensteel, S.F., Land, M.F. and Fujimoto J (Eds): Contemporary Fixed Prosthodontics. St.Louis: Mosby, 2001; 431-450.
2. Miranda, F.J., Duncanson, M.G., Collard, E.W. Comparative stability of two removable die systems. *J. Prosthet. Dent.*, 1976; **36**: 326-333.
3. Dilts, W., Podshadley, A., Ellison, E., Neiman, R. Accuracy of a removable die-dowel pin technique. *J. Dent. Res.*, 1971; **50**:1249-1252.
4. Millstein, P.L. Determining the accuracy of gypsum casts made from type IV dental stone. *J. Oral. Rehabil.*, 1992; **19**:239-243.
5. Smith, C.D., Nayyar, A., Koth, D.L. Fabrication of removable stone dies using cemented dowel pins. *J. Prosthet. Dent.*, 1979; **41**:579-581.
6. Serrano, J.G., Lepe, X., Townsend, J.D., Johnson, G.H., Theilke, S. An accuracy evaluation of four removable die systems. *J. Prosthet. Dent.*, 1998; **80**:575-586.
7. Aramouni, P., Millstein, P.L. A comparison of the accuracy of two removable die systems with intact working casts. *Int. J. Prosthodont.*, 1993; **6**:533-539.
8. Covo, L.M., Zeibert, G.J., Balthazar, Y., Christensen, L.V. Accuracy and comparative stability of three removable die systems. *J. Prosthet. Dent.*, 1988; **59**:314-318.
9. O'Brien, W.J. Dental materials and their selection, 3<sup>rd</sup> ed. Chicago: Quintessence publishing Co., Inc., 2000; 40-42.
10. Montignoni, M., Schoneberger, A. Precision fixed Prosthodontics: clinical and laboratory aspects. Chicago: Quintessence publishing Co., Inc., 1990; 167.
11. Heshmati, R.H., Nagg, W.W., Wirth, C.G., Dhuru, V.B. Delayed linear expansion of improved dental stone. *J. Prosthet. Dent.*, 2002; **88**:26-31.
12. Andritsakis, D.P. The Pindex system in the construction of removable dies. *Odontostomatol. Proodos.*, 1990; **44**:427-436.
13. Wee, A.G., Cheng, A.C., Eskridge, R.N. Accuracy of 3 conceptually different die systems used for implant casts. *J. Prosthet. Dent.*, 2002; **87**:23-29.
14. American National Standards Institute/American Dental Association 1987. Specification No. 25 for Dental Gypsum Products. Council on Dental Materials. Gaithersburg, MD, USA.
15. Gypsum compounds. In Craig, R.G. (Ed): Restorative dental materials. St Louis: Mosby, 1980:23-25.
16. Al-Abidi, K., Ellakwa, A. The effect of adding a stone base on the on the accuracy of working casts using different types of dental stone. *J. Contemp. Dent. Pract.*, 2006;**7**:17-28.