

A Comparative Evaluation of Linear Dimensional Accuracy of the Dies Obtained using Three Conceptually Different Die Systems in the Fabrication of Implant Prosthesis: An *in vitro* Study

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ABSTRACT

Statement of problem: Given that meticulous implant prosthodontic procedures are recommended to obtain the best possible intraoral fit, the die systems used for multi-implant casts warrant further investigation. Die stone expansion and errors introduced by removable die casts may exceed the accuracy required for the passive fit of implant prosthesis.

Purpose: The purpose of the study was to evaluate the linear dimensional accuracy between the implant master die and three conceptually different die systems, such as Pindex system, Accu-trac precision die system and conventional brass dowel pin system.

Materials and methods: Thirty impressions of implant master die were made with polyether impression material. Ten experimental implant casts were fabricated for each of the three different die systems tested: Accu-trac precision die tray system, Pindex system and conventional brass dowel pin system. The solid experimental casts were sectioned and then removed from the die system 30 times. Linear distances between all six possible distances were measured from one center of the transfer coping to the other, using a coordinate measuring machine in millimeters up to accuracy of 0.5 microns. Data were tabulated and statistically analyzed by binomial nonparametric test using SPSS version 15.

Results: Significant differences were found for distance A-B ($p = 0.002$), A-C ($p = 0.002$), A-D ($p = 0.002$) and B-D ($p = 0.021$) in conventional dowel pin system however, for Accu-trac precision die tray system it was significant only for distance A-D ($p = 0.002$) but for Pindex system it was nonsignificant for all the distances measured.

Conclusion: Within the limitations of this study, use of Pindex system is recommended when sectioned dies are needed for a multi-implant retained prosthesis.

Keywords: Pindex system, Conventional brass dowel system, Accu-trac die tray system.

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INTRODUCTION

The advent of implant dentistry has redefined the need for accuracy of working cast models. Although true passive fit

of multi-implant-supported prostheses to their intraoral implant abutments does not seem attainable, the degree of implant prosthesis misfit that will lead to complications is unclear. For this reason, meticulous and accurate implant prosthodontic procedures are recommended to obtain the best possible fit to avoid bone strain resulting from uncontrolled loading of implants through superstructure.¹⁻⁵

The inherent setting expansion of the die stone used is one of the variables that can affect the quality of working cast during its fabrication and use. Improved type IV and type V dental stones, which are normally used for the first pour of an impression, and type III stone, which is used for the base pour, have an inherent setting expansion that makes it impossible to reproduce exactly the original tooth position in the working cast.⁶⁻¹⁰

This *in vitro* study was oriented to evaluate the linear dimensional accuracy between the implant master die and three conceptually different die systems, such as Pindex system, Accu-trac precision die system and conventional brass dowel pin system.

AIM AND OBJECTIVES

1. To evaluate the linear dimensional accuracy between the implant master die and three conceptually different die systems, such as Pindex system, Accu-trac precision die system and conventional brass dowel pin system.
2. To determine the amount of discrepancy along the linear dimension between the abutments of the implant cast and the corresponding distance in the master die.

MATERIALS AND METHODS

An aluminum master die was fabricated to simulate the mandibular edentulous arch. Four equal sized vertical holes of diameter 5.5 mm and length 13 mm corresponding to the size of an implant analog (D5.5/L13 Frialit-2, Dentsply, Germany) were drilled. Stainless steel implant analogs were cemented into their respective drilled holes with adhesive resin cement (3M ESPE RelyX U 100). Transfer copings (GH3, Frialit-2, Dentsply, Germany) were tightened upon the implant analogs and were labeled A through D (Fig. 1). From this master die, a total of 30 impressions, 10 for each die system were obtained (Flow Chart).

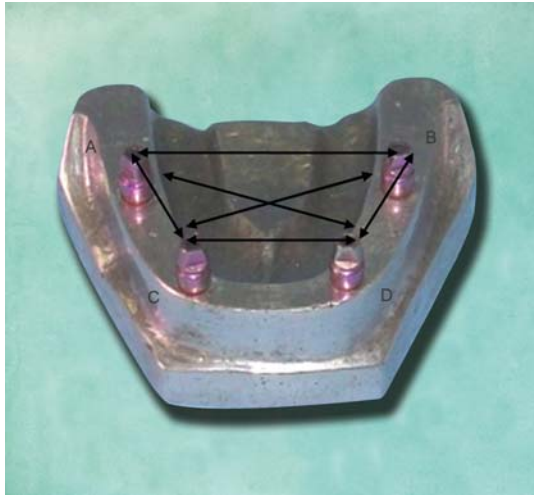
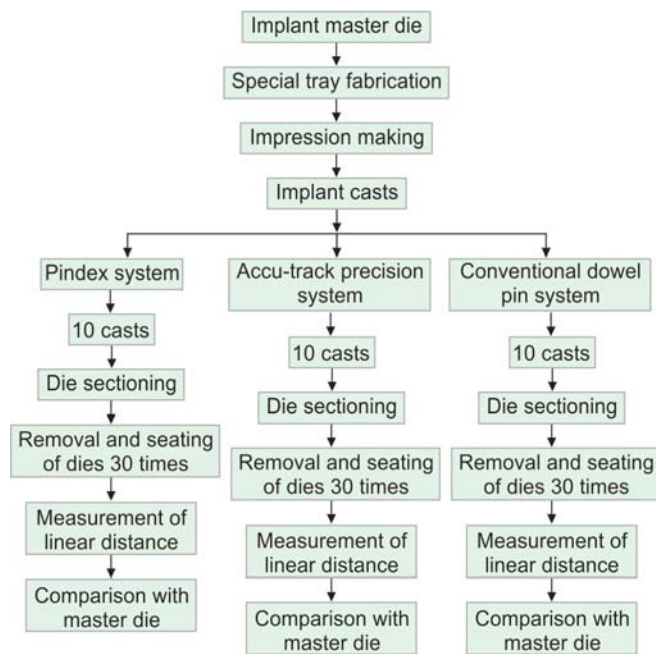


Fig. 1: Implant master die



Flow Chart: Steps followed during the fabrication of master die for three different die systems and their comparison with implant master die

Impression Making and Master Cast Fabrication for each Die System

To ensure uniform thickness of spacer, wax spacer design of 5 mm thickness (Hindustan dental products, India) was adapted uniformly upon the implant master die and duplicated using putty impression material (Aquasil, Dentsply). The duplicated cast was used in the fabrication of special trays.¹¹⁻¹³ The custom tray was coated with tray adhesive (3M ESPE, Germany) and a total of 30 impressions, using double-mix-single impression technique were made with polyether impression material (Impregnum Soft, 3M ESPE, Germany) according to manufacturer's guidelines.¹⁴ The impressions were examined for voids and

defects and aged for 30 minutes before pouring the cast.¹⁵⁻¹⁷ Transfer copings along with implant analogs were inserted into the impression with flat surfaces precisely oriented. The mixed Type 4 die stone (Kalstone, Kalabhai, Karson Pvt. Ltd., India) was carefully expressed over the periphery of the impression until it was completely filled. All casts were then allowed to set for 30 minutes ensuring complete setting.^{18,19}

Accu-Trac Precision Die Tray System

After a setting period of 30 minutes, the casts were trimmed to a 'horse-shoe' configuration which allowed the casts to fit within the confines of the Accu-trac tray (Carson Dental, Freud Dental Company).²⁰ Retentive grooves were prepared on the inferior surface of the casts using BP blade and vacuum mixed Type 4 die stone was filled into the retentive grooves on the cast and then vibrated into the die tray.

After allowing the casts to set for 30 minutes, the hinged arm of the tray was unlocked and casts were removed from the die trays (Fig. 2). After 24 hours, vertical saw cuts were made through the indentations on the base with a jeweler's saw (ICNA, 370 AY-Swiss) and dies were trimmed of all rough surfaces (Fig. 3).²¹ Each die was inserted and removed 30 times to simulate the average number of times, the dies would be removed and seated during laboratory use (Fig. 4). By using a coordinate measuring machine, the distance between A-B, A-C, A-D, B-C, B-D and C-D were measured and tabulated.

Pindex System

Four holes were made on the underside of the cast replicating the center of transfer coping by using a light source of the Pindex machine (Coltene/Whaledent). Double straight dowel pins with a common head (Twin Pin, R and D Dental, Korea) were cemented into their respective holes with cyanoacrylate adhesive (Fig. 5). Metal sleeves were fitted



Fig. 2: Grooves on undersurface of the base of cast



Fig. 3: Sectioned dies in Accu-trac die tray



Fig. 6: Metal sleeves seated into the twin pins



Fig. 4: Unlocked arm with dies outside the tray

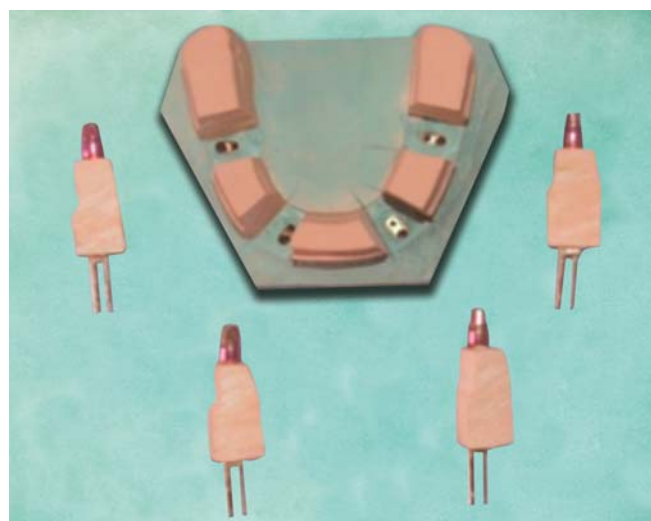


Fig. 7: Sectioned dies outside the master cast



Fig. 5: Twin pins cemented into the hole

into each cemented pins (Fig. 6).²² Separating media was applied onto the removable die sections adjacent to the pins. Undercut grooves were prepared on the inferior surface of

the casts for retention. Type III dental stone mix was poured on the cast and into the base former and allowed to set for 60 minutes.

After 24 hours, casts were subjected to die cutting, making certain that the saw cuts taper slightly, being farthest apart at the occlusal surface and closer at the base. Dies were removed gently by taping and loose debris was removed from the dies (Fig. 7). Dies were carefully trimmed with a BP blade to prevent binding. Four sectioned dies were removed and seated 30 times into their respective position to simulate the laboratory usage of the dies.

Conventional Brass Dowel Pin System

Bobby pins were used to position and stabilize the brass dowel pins (Fig. 8). One flat-sided straight brass dowel pin (R and D Dental, Korea) per removable section was used. After a setting period of 30 minutes, casts were removed from the impression and trimmed by a center grinder machine to remove any undercuts. Separating media were

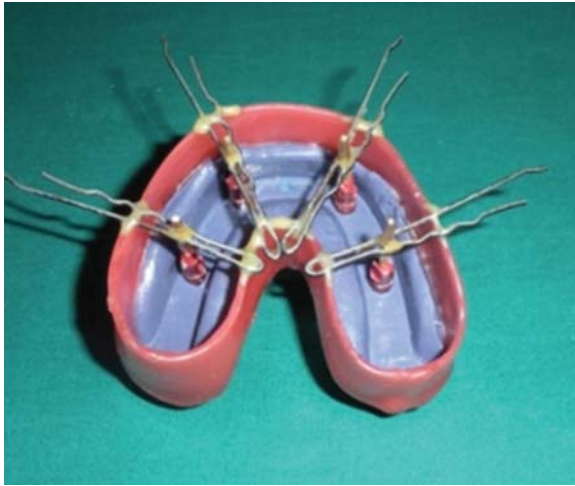


Fig. 8: Bobby pin with dowel pin

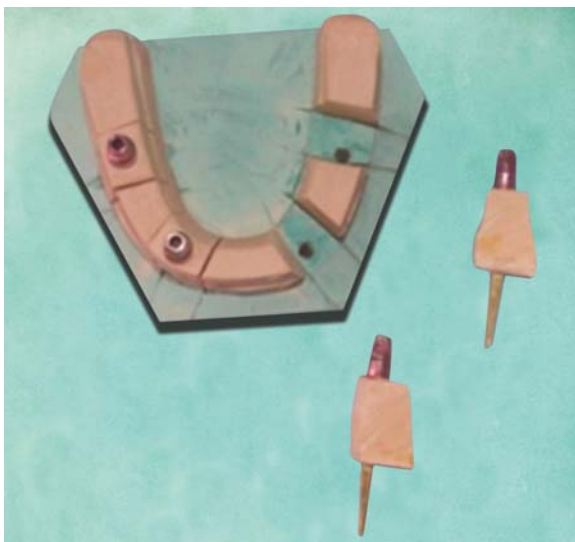


Fig. 9: Dies outside the master cast

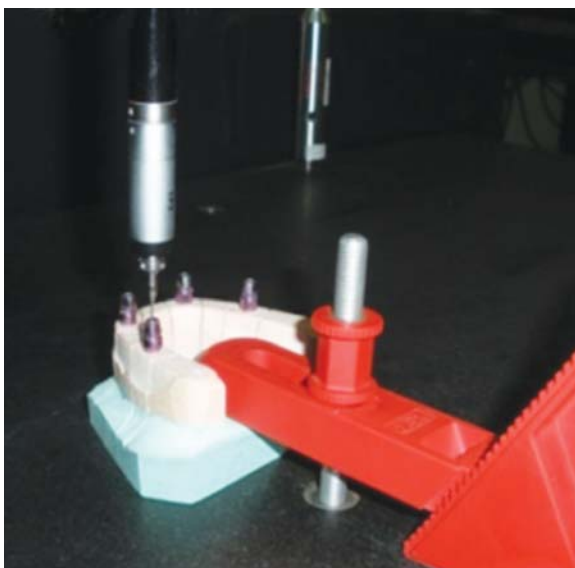


Fig. 10: Measurements by coordinate measuring machine

applied onto the removable die sections while avoiding the retentive knobs. Small wax balls were placed on the tip of

each dowel pins to locate the exact position of dowel pin. The Type IV dental stone mix was placed in the retentive knobs on the cast and then vibrated into the base former.²³ After 24 hours, position of the each saw cut was marked, slightly converging toward the pins for easy removal of the dies. With a jeweler's saw, dies were sectioned (Fig. 9). Each die was later removed and seated 30 times to simulate average handling during laboratory procedures (Fig. 10).²³

Coordinate Measuring Machine

Measurement of Master casts by Coordinate Measuring Machine

After removing and seating each die 30 times, all six possible distances between A-B, A-C, A-D, B-C, B-D and C-D were measured from one center of the transfer coping to the other, using a coordinate measuring machine (Mitutoyo Corporation, Japan) in millimeters up to accuracy of 0.5 microns.²⁴

RESULTS

Measurements of all six distances were tabulated and statistically analyzed by binomial nonparametric test using SPSS version 15. Box plots diagrams for all six distances were plotted for each die system.

Box Plot for Distance A-B

Assuming implant master die as standard zero, Accu-trac die tray system, Pindex system and conventional brass dowel pin system showed median variation of 0.056, -0.0097 and -0.1065 respectively. Thus, Pindex system was most close to the gold standard of implant master die (Table 1). p-value of Pindex system (p=0.754) and Accu-trac system (p=0.754) were insignificant, however it was highly significant (p = 0.002) for conventional brass system (Graph 1).

Box Plot for Distance A-C

Median variation of Pindex system (-0.0761) was closest to zero and then was Accu-trac precision die system (-0.0861). However, for conventional brass dowel pin (-0.2218) system, it was very much away from gold standard zero of implant master die (Graph 2). p-value of conventional brass pin system (0.002) was highly significant (Table 1). However it was insignificant for Accu-trac system (p value = 0.109) and Pindex system (p = 0.102).

Box Plot for Distance A-D

Accu-trac system (p-value = 0.002) and conventional brass pin system (p-value = 0.002) were highly significant. It

Table 1: Measurements of all six distances for three different die systems

Distance	Accu-trac system			Pindex system			Brass pin system		
	Median (in mm)	q1, q2 (in mm)	p-value	Median (in mm)	q1, q2 (in mm)	p-value	Median (in mm)	q1, q2 (in mm)	p-value
A-B	0.056	-0.0361, 0.1494	0.754	-0.0097	0.0906, 0.0260	0.754	-0.1065	-0.1872, -0.0822	0.002
A-C	-0.0861	-0.1811, -0.0205	0.109	-0.0761	-0.1287, -0.0322	0.102	-0.2218	-0.4017, -0.1336	0.002
A-D	-0.1157	-0.1770, -0.0625	0.002	-0.0546	-0.1555, 0.055	0.344	-0.5900	-0.9069, -0.1973	0.002
B-C	-0.0589	0.1318, 0.0987	0.344	-0.0391	-0.0579, -0.0243	0.109	-0.1472	-0.3067, 0.3054	0.754
B-D	0.1064	-0.0341, 0.1454	0.754	-0.0309	-0.0838, 0.0169	0.344	-0.2832	-0.3403, -0.1741	0.021
C-D	0.0099	-0.0758, 0.2338	1.000	-0.0060	-0.0737, 0.0261	1.000	-0.1182	-0.1416, -0.0177	0.109

showed more error for distance A-D in these two systems with respect to implant master die (Graph 3). However, it was non-significant (p -value = 0.344) for Pindex system (Table 1).

Box Plot for Distance B-C

The distance between B-C was nonsignificant for all the three die systems (Graph 4). But median of Pindex system was almost zero in Box plot diagram which means that there is least amount of discrepancy in this system and the distance measured is almost equal to the implant master die (Table 1).

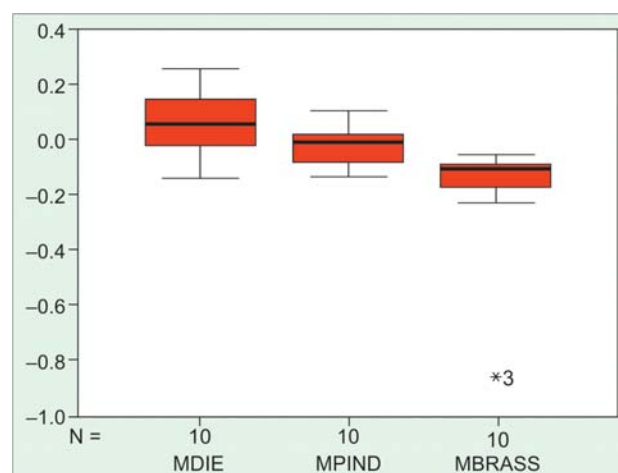
Box Plot for Distance B-D

Median variation of Pindex system (median = -0.0309) was closest to the gold standard of implant master die (Table 1). Median of conventional brass dowel pin system (median = -0.2832) was very much away from the zero (Graph 5). p -value of conventional brass dowel pin was significant (p = 0.021).

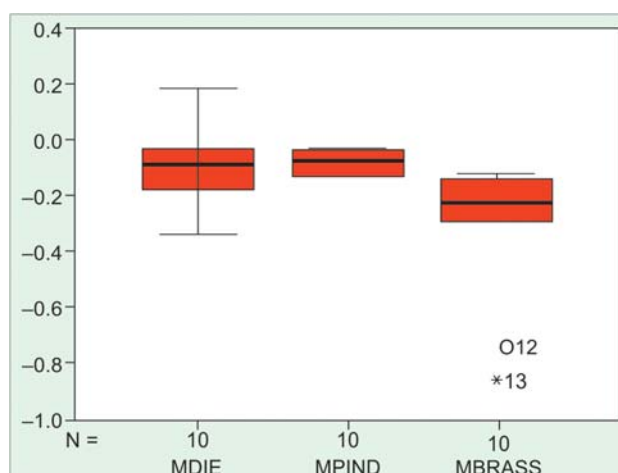
Box Plot for Distance C-D

This table indicates that for all the three die systems p -value was nonsignificant, however Pindex system (median = -0.0060) was very much close to zero, then Accu-trac precision die tray system (median = 0.0099) and after that conventional brass dowel pin system (median = -0.1182) (Table 1 and Graph 6).

The data obtained from this study revealed that a significant difference exists between the conventional dowel pin system for distance A-B (p = 0.002), A-C (p = 0.002), A-D (p = 0.002) and B-D (p = 0.021) however, for Accu-trac precision die tray system it was significant only for distance A-D (p = 0.002) but for Pindex system it was nonsignificant for all the distances measured.



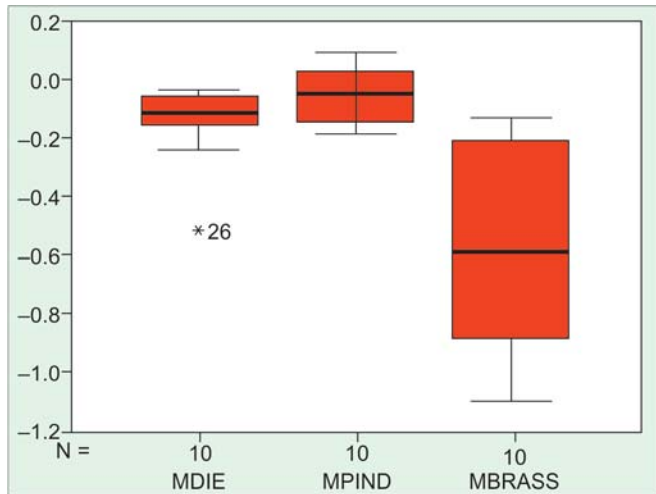
Graph 1: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance A-B



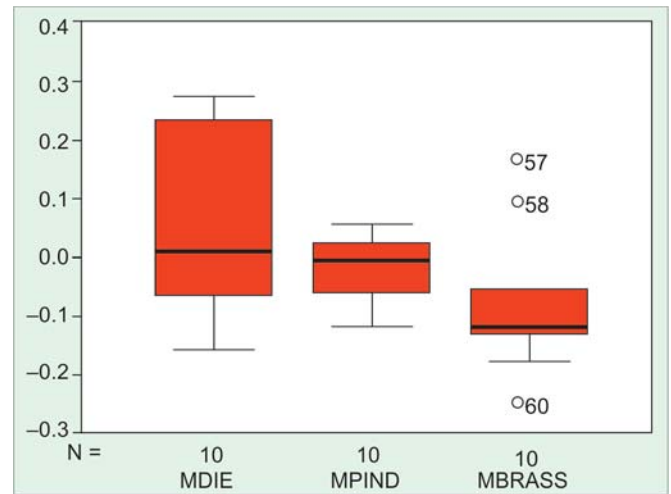
Graph 2: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance A-C

DISCUSSION

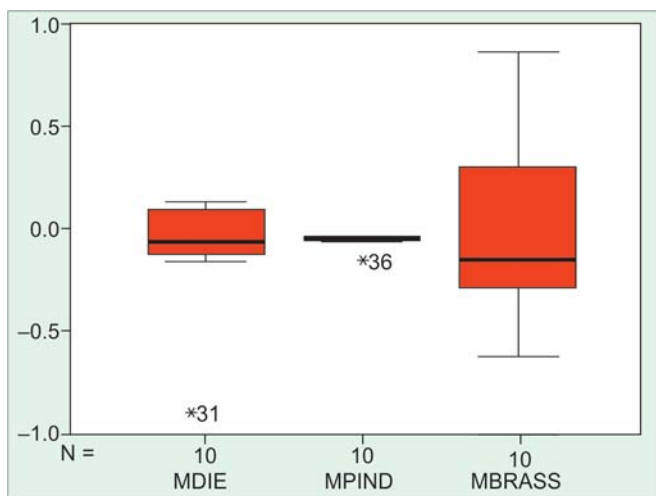
Removable dies for working casts are a valuable asset during the laboratory phase of implant-supported fixed partial



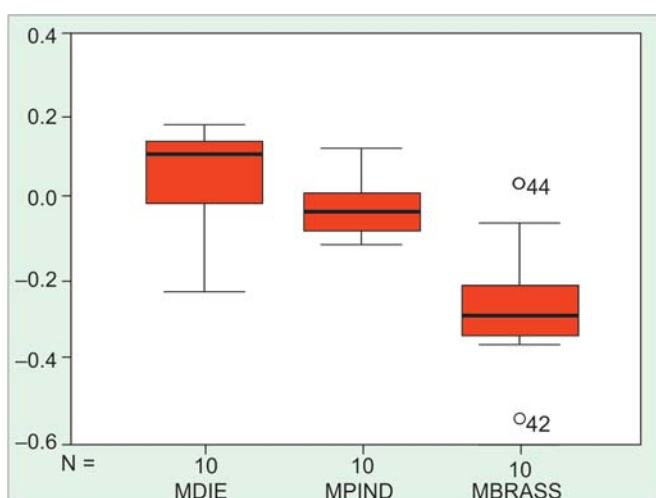
Graph 3: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance A-C



Graph 6: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance C-D



Graph 4: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance B-C



Graph 5: Comparison of the median values for Accu-trac precision die, pindex and brass dowel pin system for distance B-D

inverted and those casts containing dies must be easy to mount on an articulator.^{25,26}

This study was designed to compare the Accu-trac precision die tray system, conventional brass dowel pin system (pins are oriented before pouring cast) and Pindex system (pins are fixed after the first pour) with the implant master die which was used as gold standard for the comparison.

Accuracy of Pindex system and Accu-trac precision die tray system (except for one distance between A-D) is explained by the fact that the removable dies are locked securely by metal sleeves in Pindex system and by indentations in Accu-trac precision die tray system. In contrast, conventional brass dowel pin has stone to stone and stone to pin interface.

Pindex system showed the least movement due to the presence of two metal pins in the stone base which were housed by metal sleeves, while conventional brass dowel pin system has only one pin and no housing. The residual setting expansion of stone would build up stresses around the die pin and create pressure, which may in turn prevent the pins from fully seating and this may also offset the initial rotation of the dies on release after sectioning. The resultant improper fit after 30 cycles of removal and insertion of the dies may prevent full seating of dies in conventional brass dowel pin system and Accu-trac precision die tray system.

Conventional brass dowel pin required an extra effort to separate after sectioning, possibly because of the binding of the pins with stone. Once it was separated, there did not seem to be the same binding force as when the dies were repositioned. In contrast conventional dowel pin does not have the plastic component as in Accu-trac die tray, but instead has stone to stone and stone to pin interface. Initial separation and subsequent cycling was significantly more passive for brass dowel pin and can easily explain the cause

denture fabrication. However, the basic requirements of any die system should be such that, the dies must return to their exact original position, must remain stable even when

for more linear discrepancies in conventional brass dowel pin system.

CONCLUSION

1. Pindex system was the most accurate among all the three die systems.
2. Within the sectioned stage, conventional brass dowel pin system produced least accurate casts than the other two die systems tested.
3. Of the three approaches analyzed in this study, only Pindex system provided the greatest amount of precision. Therefore, when sectioned dies are needed in implant dentistry, the use of Pindex system first and then Accutrac precision die tray system is recommended. However conventional brass dowel pin system is not advisable.

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