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ORIGINAL RESEARCH

Comparison of Dimensional Accuracy of Four Different Die Materials before and after Disinfection of the Impression: An *in vitro* Study

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ABSTRACT

Background: This study was conducted to compare the linear dimensional accuracy of die materials before and after disinfection of the impression. Type IV and V conventional dental stone, type IV-resin impregnated and copper-plated die materials were studied.

Materials and methods: A stainless-steel master die analogs to a complete veneer crown preparation with three scribed lines (I: vertical, II and III: horizontal) was machined and measurements were made from these scribed reference lines. Impressions were made with monophase addition silicone impression material for each of the specimens. 2% glutaraldehyde was used as a disinfectant. The fabricated dies were measured to the nearest 0.0001 mm. ANOVA and post hoc was carried out using Scheffe multiple comparison test at significance level of 0.05.

Results: Type IV resin-impregnated dental stone and copper-plated dies approximated the dimensions of the master die. Type IV and V conventional dental stone dies showed greater variation in measurements. Statistically significant differences were observed for type IV resin-impregnated and copper-plated dies in dimension I and III. For dimension II no significant differences were found for dies fabricated from four die materials. A one-way analysis of variance indicated no statistical significant differences among the two groups of dies fabricated from disinfectant treated impressions and those fabricated from nondisinfectant treated impressions.

Conclusion: Type IV resin-impregnated dental stone and copper-plated dies are dimensionally more accurate than type IV and V conventional dental stone die materials. No significant linear distortion in the dies fabricated from the disinfected impressions was observed.

Keywords: Die materials, Dimensional accuracy, Disinfection.

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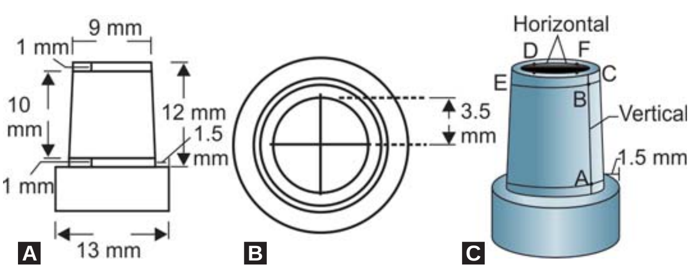
INTRODUCTION

The accurate duplication of prepared teeth is essential for the fabrication of fixed prosthesis.[1] The fit and ultimate clinical success of cast dental restorations depends upon the accuracy, completeness of die reproduction and durability of the resultant die, which is subject to possible deformation during the process of fabrication used to construct a cast restoration.[2] Improved dental stones are used for producing dies for the fabrication of restorations due to the perceived dimensional accuracy, low cost and ease of use. But they have less than ideal abrasion resistance, strength and detail reproduction. These properties render a die susceptible to dimensional change during laboratory procedures. Alternative die materials such as copper-plated and resin-impregnated gypsum have been shown to possess superior abrasion resistance, strength and detail reproduction. Some investigators have found electroplated dies to be more dimensionally accurate than stone dies while others have demonstrated otherwise.[3]

The awareness of infectious diseases and the recognition of the potential for transmission of infection during dental procedures have increased concern and attention to infection control in dental practice.[4] Disinfection provides a method of preventing the transmission of these microorganisms from the patient to dental personnel who handle the impression or stone cast.[5] It is conceived that chemical solutions may adversely affect detail reproduction or dimensional stability of the impression material.[6] Hence, this study was undertaken to compare the linear dimensional accuracy of four different die materials including type IV, type IV-resin impregnated, type V and copper-plated die materials before and after disinfection of the impression.

MATERIALS AND METHODS

A stainless steel master die analogs to a complete veneer crown preparation was machined to the specifications originally described by Bailey et al[7] with a vertical dimension of 12 mm from the cavosurface line angle to the occlusoaxial line angle, diameter of 13 mm at the cavosurface line angle with convergence angle of 5° providing a diameter of 9 mm at the occlusal end of the die and the shoulder width of 1.5 mm wide. Two mutually perpendicular lines intersecting at the center of the occlusal surface were scribed. With the intersection of these two scribed lines as its center, a 3.5 mm circle was scribed. On the occlusal surface, the four points at which the circle intersected the scribed lines were used to record dimensions by measuring the distance between the two points along each scribed line. Two lines each in a plane perpendicular to the long axis of the die were scribed circumferentially onto the surface of the axial wall of the die, one line located 1mm gingivally from the occlusoaxial line angle and other 1mm occlusally from the axiogingival line angle. Another line was scribed along the vertical axis of the die. The measurement between the circumferential lines at the vertical axis line (Point A-Point B) was referred to as dimension I. The occlusal line intersecting the vertical axis line (Point C-Point D) was referred to as dimension II. The occlusal line perpendicular to dimension II (Point E-Point F) was referred to as dimension III (Figs 1A to C). Two millimeters of relief was provided over the master die for the impression material and a stainless steel tray was made over the die to make the impressions. Alignment guide and stop were made on the tray and die for proper positioning of the tray on the die (Fig. 2). A total of 128 impressions were made with monophase addition silicone impression material with adhesive retention used within the tray. The impressions were allowed to set as per the manufacturer's recommended time (Fig. 3). Those impressions which were to be disinfected were immersed in 2% glutaraldehyde for 30 minutes.



Figs 1A to C: Diagrammatic representations of the master die with its dimensions: (A) Lateral view, (B) End-on view and (C) 3-dimensional view

Fig. 2: Machined stainless steel master die analogs to a complete veneer crown preparation

Fig. 3: Impression of the die

Fabrication of Dies

Thirty two dies were made from each of the three gypsum based die materials: type IV and V conventional dental stone and type IV resin-impregnated dental stone. The die materials were proportioned and hand mixed following the manufacturer's recommended water: powder ratio (Table 1). The stone was vibrated into the impression and allowed to set for 1 hour at room temperature, following which the dies were recovered from the impressions for measurement.

Another set of 32 electroplated dies were fabricated using copper plating apparatus. The composition of the copper plating solution consisted of copper sulfate (crystals) 200 mg, sulfuric acid 30 ml, phenolsulfonic acid 2 ml and distilled water 1000 ml.[8]

Table 1: Die materials tested and mixing proportions

Product	*Type*	*Manufacturer claimed expansion (in %)*	*H_2O/ powder ratio*
Kalrock	Type IV	0.10%	23 cc/100 gm
Hard rock	Type V	0.25%	21 ml/100 gm
Resin rock	Type IV resin-impregnated	0.14%	20 ml/100 gm

The impression surfaces were made conductive by the application of a thin layer of silver paste using a fine bristle brush and allowed to dry. A copper wire was connected to the impression was then connected to the negative terminal of the power source. The impression was placed in the electroplating solution. The platinum anode was connected to the positive terminal of the power source. Current was set at 15 mA for 1 hour and then increased to 45 mA for next 12 hours. All impressions were electroplated individually. Following electroplating, the impressions were rinsed with water, dried and poured up with die stone (Fig. 4). The die stone was allowed to set for 1 hour, following which the dies were recovered from the impressions for measurement.

Grouping of Dies

A total of 128 dies were fabricated. They were divided in to 8 groups, each consisting of 16 dies as follows:

Group A: Type IV conventional dental stone dies fabricated from nondisinfectant treated impressions.

Group B: Type IV resin-impregnated dies fabricated from nondisinfectant treated impressions.

Group C: Type V conventional dental stone dies fabricated from nondisinfectant treated impressions.

Group D: Copper-plated dies fabricated from non-disinfectant treated impressions.

Group 1: Type IV conventional dental stone dies fabricated from disinfectant treated impressions.

Group 2: Type IV resin-impregnated dies fabricated from disinfectant treated impressions.

Group 3: Type V conventional dental stone dies fabricated from disinfectant treated impressions.

Group 4: Copper-plated dies fabricated from disinfectant treated impressions.

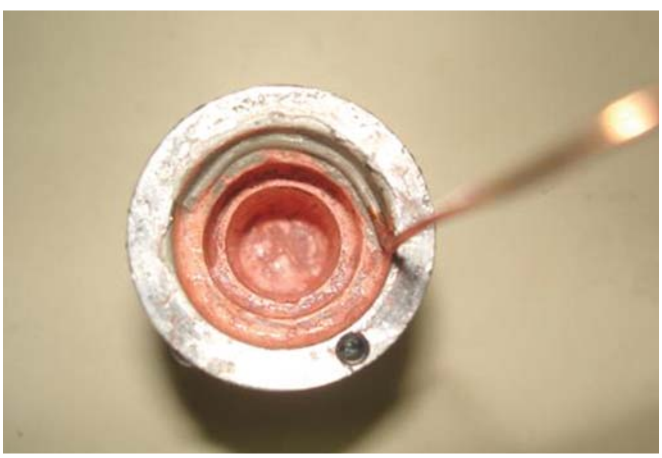


Fig. 4: Copper plated impression

Evaluation of Dimensional Accuracy

Dimensional accuracy was evaluated by measuring dimension I, II and III in all the dies. The master die measurements was arrived at from mean of four measurements taken for each of the three dimensions to the nearest 0.0001 mm, at the original magnification of 50× using video vision measuring microscope (Fig. 5). All the 128 dies were measured in the same manner as the master die. The 3 measured dimensions were averaged and compared with the measurements of dimensions on the metal master die.

STATISTICAL ANALYSIS

Statistical analysis (ANOVA) was performed to determine the significance between the dimensions and types of materials. The difference in mean dimensional change along with the types of material was evaluated using one-way analysis of variance and post hoc test was conducted using Scheffe multiple comparison test. p-value ≤ 0.05 was considered to be statistically significant. Comparison of mean values between the two groups of dies fabricated from disinfectant treated impressions and those fabricated from nondisinfectant treated impressions was conducted using one-way ANOVA.

RESULTS

The master die measurements, mean values and standard deviation for all dimensions for each of the die material are presented in the Table 2 (dies fabricated from non-disinfectant treated impressions) and Table 5 (dies fabricated from disinfectant treated impressions). The dimensional differences (in percentage) from the master die for each material are shown in Tables 3 and 6. Type IV resin-impregnated and copper-plated dies most closely approximated the dimensions of the master die. Type IV and V conventional dental stone dies recorded the greatest variation in dimensions. Tables 4 and 7 shows the results

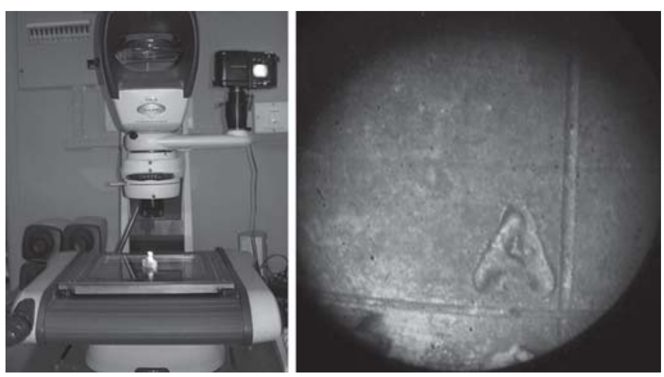


Fig. 5: Video vision measuring microscope and the observed microscopic image at Point A of the die

Table 2: Master die measurements, mean values and standard deviation for dies fabricated from nondisinfectant treated impressions

Die	*Dimension I*		*Dimension II*		*Dimension III*	
	AB	*SD*	*CD*	*SD*	*EF*	*SD*
Master die	9.9236		6.6448		6.6545	
Group A: Type IV (Kalrock)	10.0211	0.0226	6.6614	0.0008	6.6793	0.0067
Group B: Type IV resin impregnated (Resin rock)	9.9235	0.001	6.8353	0.7494	6.6637	0.0007
Group C: Type V (Hard rock)	10.0000	0.0263	6.6298	0.0400	6.6643	0.0071
Group D: Copper-plated die	9.9146	0.0001	6.6446	0.0226	6.6645	0.0001

Measurements in millimeters

Table 3: Dimensional differences from master die in percent

Material	*Dimension I change*	*Dimension II change*	*Dimension III change*
Group A: Type IV (Kalrock) dies	0.9750%	0.1660%	2.4800%
Group B: Type IV resin impregnated (Resin rock) dies	0.0010%	1.9050%	0.0920%
Group C: Type V (Hard rock) dies	0.7640%	–0.1500%	0.0980%
Group D: Copper-plated dies	–0.0900%	–0.0200%	1.0000%

Table 4: Results of statistical analysis

Variable	*Difference*
Mean dimensional change (Dimension I)	RI, CP < Type V , Type IV
Mean dimensional change (Dimension II)	No statistical significance
Mean dimensional change (Dimension III)	RI, CP < Type V , Type IV

< denotes statistically significant difference (Results of Scheffe post hoc test with significance level 0.05)

Table 5: Master die measurements, mean values and standard deviation for dies fabricated from disinfectant treated impressions

Die	*Dimension I*		*Dimension II*		*Dimension III*	
	AB	*SD*	*CD*	*SD*	*EF*	*SD*
Master die	9.9236		6.6448		6.6545	
Group 1: Type IV (Kalrock)	10.0153	0.0004	6.6592	0.0044	6.6763	0.0028
Group 2: Type IV resin impregnated (Resin rock)	9.9233	0.0011	6.6465	0.0051	6.6638	0.0006
Group 3: Type V (Hard rock)	10.0120	0.0062	6.6520	0.0366	6.6842	0.0227
Group 4: Copper-plated die	9.9154	0.0023	6.6466	0.0057	6.6644	0.0002

Table 6: Dimensional differences from master die in percent

Material	*Dimension I change*	*Dimension II change*	*Dimension III change*
Group 1: Type IV (Kalrock) dies	0.9170%	0.1440%	0.2180%
Group 2: Type IV resin impregnated (Resin rock) dies	–0.0030%	0.0170%	0.0930%
Group 3: Type V (Hard rock) dies	0.8840%	0.0720%	0.2170%
Group 4: Copper-plated dies	–0.0820%	0.0180%	0.0990%

of the statistical analysis (Scheffe post hoc test with significance level 0.05). Statistical differences were observed for type IV resin-impregnated and copper-plated dies in dimension I and III, compared to type IV and V conventional dental stone dies fabricated from disinfectant treated and nondisinfectant treated impressions. For dimension II no significant differences were found for dies fabricated from four die materials. A one-way analysis of variance (ANOVA) indicated no significant differences among the two groups of dies fabricated from disinfectant treated impressions and those fabricated from nondisinfectant treated impressions (Table 8).

DISCUSSION

The dimensional accuracy of the die material is important for accurate final restoration. The different die materials available for the fabrication of dies in fixed prosthodontics include the type IV and V conventional dental stone, type IV resin-impregnated dental stone, epoxy resin and electroplated dies. Toreskog et al tested eight different classes of die materials and concluded that no material was superior.[9] Newman and Williams also concluded that an ideal universal die material is yet to be produced.[10]

Gypsum die materials have been reported to exhibit a setting expansion of 0.01 to 0.1%. This minimal expansion

Table 7: Results of statistical analysis

Variable	*Difference*
Mean dimensional change (Dimension I)	RI, CP < Type V ,Type IV
Mean dimensional change (Dimension II)	No statistical significance
Mean dimensional change (Dimension III)	RI, CP < Type V ,Type IV

< denotes statistically significant difference (Results of Scheffe Post hoc test with significance level 0.05).

Table 8: Comparison of mean values among the two groups dies fabricated from disinfectant treated (DT) impressions and from nondisinfectant treated (NDT) impressions

	Dimension I		*Dimension II*		*Dimension III*	
Type IV Kalrock dies	*Group 1*	*Group A*	*Group 1*	*Group A*	*Group 1*	*Group A*
Mean	10.0153	10.0211	6.6592	6.6614	6.6763	6.6793
SD	0.0004	0.0226	0.0044	0.0008	0.0028	0.0067
F	0.991		3.63		2.77	
p-value	0.33		0.07		0.11	
Type IV Resin rock dies	*Group 2*	*Group B*	*Group 2*	*Group B*	*Group 2*	*Group B*
Mean	9.9233	9.9235	6.6465	6.8353	6.6638	6.6637
SD	0.0011	0.001	0.0051	0.7494	0.0006	0.0007
F	0.52		1.02		0.20	
p-value	0.48		0.32		0.66	
Type V Hard rock dies	*Group 3*	*Group C*	*Group 3*	*Group C*	*Group 3*	*Group C*
Mean	10.0120	10.0000	6.6521	6.6298	6.6842	6.6643
SD	0.0062	0.0263	0.0366	0.0400	0.0227	0.0071
F	3.11		2.70		3.25	
p-value	0.09		0.11		0.07	
Copper-plated dies	*Group 4*	*Group D*	*Group 4*	*Group D*	*Group 4*	*Group D*
Mean	9.9154	9.9146	6.6466	6.6446	6.6644	6.6645
SD	0.0023	0.0001	0.0057	0.0001	0.0002	0.0001
F	2.23		1.93		0.16	
p-value	0.15		0.18		0.69	

Any p-value ≤ 0.05 was considered to be statistically significant

has been said to compensate for the dimensional changes inherent in the fabrication process of an indirect restoration. There are several disadvantages to its use in the fabrication of dies due to its poor abrasion resistance, potential variability in fine detail reproduction and inadequate tensile strength which are necessary for the production of certain restorations such as all porcelain margins, long and narrow preparations.[11]

The use of resin die materials which contains incorporation of hydrocarbon-based polymers as a noncovalent composite (nonbonding) filler to reduce the brittle nature of gypsum die material[12] and resin coatings on gypsum dies has been investigated. In another study, the linear dimensional change, detail reproduction, surface hardness, abrasion resistance and transverse strength of resin-modified gypsum die materials (Resin rock and Mile stone), epoxy resin die material (Epoxy-die) and 2 conventional type IV gypsum die materials (Silky rock and Die-Stone) were evaluated. All gypsum products expanded, whereas the epoxy resin material contracted during setting. The resin modified gypsum products were not significantly superior to the conventional type IV gypsum die materials.[13]

Cassimatey found electroplated dies to be more dimensionally accurate than stone dies.[14] Bailey et al showed that improved dental stone dies had the greatest variation in measurements of the 3 die systems examined, epoxy resin dies were next and silver plated dies showed the least variation.[7]

In this study the type IV resin-impregnated and copper-plated dies most closely approximated the master die with respect to the three-dimensions measured. In previous studies statistical differences were observed for type IV resin-impregnated and copper-plated dies in dimension I only compared to the other five die materials. In our study statistical differences were observed for type IV resin-impregnated and copper-plated dies in dimension I and III compared to type IV and V conventional dental stone dies. No significant differences were found for dies fabricated from nondisinfectant treated impressions along dimension II.

The fit and ultimate clinical success of a cast dental restoration depends on an accurate, strong, abrasion resistant die material with good detail reproduction. The use of dimensionally accurate materials such as type IV resin-impregnated and copper-plated dies should result in the development of a crown margin that lies in more intimate contact with the finish line of the tooth preparation, given that the dimensional changes of the wax pattern, alloy and investment are carefully matched.[3] Type IV and V gypsum dies recorded the greatest variation in dimensions than the other die materials examined. The minimal setting expansion of conventional type IV and V dental stone should result in the fabrication of satisfactory crown margins and provide enough space between the casting and the tooth to allow complete seating without binding and space for a film of cement.[3]

The poor strength and abrasion resistance of conventional type IV and V dental stone become more significant in complex fixed prosthodontics, when transfer copings are necessary or when fabricating all porcelain margins. Of the tested materials, type IV resin-impregnated and copper-plated dies are recommended for these cases because of their strength, abrasion resistance and dimensional accuracy. If maximum strength and abrasion resistance are required, copper-plated dies could be used. If less abrasion resistance is needed or ease of construction is essential, type IV resin-impregnated dies is recommended.

Though copper-plated dies are considered to be dimensionally accurate convenience is not one of the positive characteristics of the copper electroplating technique. It involves special equipment, materials and more number of steps requiring 10 to 15 hours until it is ready for use and is incompatible with many impression materials. In addition, the fabrication of copper-plated dies can be more technique sensitive compared with other die materials. The impression surfaces must be delicately coated with a thin layer of silver paste to achieve an accurate, smooth, even layer of plated metal with good detail. The sectioning and trimming of copper plated dies must be performed carefully to avoid damaging the margin or adjacent proximal contacts.[3]

The prevalence of the human immunodeficiency virus (HIV) and other infectious diseases in blood and other body fluids has influenced the necessity for personal protection and the prevention of disease transmission. Dental impressions contact saliva and blood, immersion disinfection is used as a method of preventing microorganism transmission from the patient to dental personnel. Several studies have reported that elastomeric impressions disinfected by immersion exhibited no detrimental, clinically significant results relative to the accuracy of the impression or subsequent stone cast.[15] Toh et al found that polyvinyl siloxane exhibited dimensional changes after a 30-minute immersion in iodophor or glutaraldehyde, whereas Merchant et al noted no change.[6]

In this study comparison of dimensional accuracy of four different die materials fabricated from impressions which were disinfected was done. The type IV resin-impregnated and copper-plated dies most closely approximated the master die with respect to the three dimensions measured. Statistical differences were observed for type IV resin-impregnated and copper-plated dies in dimension I and III compared to type IV and V conventional dental stone dies. For dimension II no significant differences was found for dies fabricated from disinfectant treated impressions. Greater magnitude dimensional differences from the master die was observed for type IV and V conventional dental stone dies fabricated from disinfected treated impressions.

CONCLUSION

Type IV resin-impregnated dental stone and copper-plated dies fabricated from both disinfectant treated and non-disinfectant treated impressions was more dimensionally accurate than the other die materials examined. Type IV and V conventional dental stone dies fabricated from both disinfectant treated and nondisinfectant treated impressions had the greater variation in measurements of the four die materials examined.

No statistically significant differences were found in the accuracy among the two groups of dies fabricated from both disinfectant treated and nondisinfectant treated impressions. This study shows that immersion disinfection of the rubber impression materials does not cause distortion of the impression that would therefore result in an unacceptable die. It provides research support for the ADA recommendation that rubber impressions be disinfected by immersion in glutaraldehyde.

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