



LINEAR DIMENSIONAL ACCURACY OF VARIOUS GYPSUM MATERIALS – AN INVITRO STUDY

Dental Science

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ABSTRACT

Aim:

To compare the linear dimensional accuracy of die prepared from gypsum materials using different mixing technique made from different impression materials.

Materials and method:

Two hundred and forty impressions of the master die were made using polyvinyl siloxane (Group A) and alginate (Group B) impression material with one hundred and twenty samples each. In each group thirty dies were made for a gypsum material with ten dies per mixing technique- hand mixing, hand and vacuum mixing and vacuum mixing. The dimensions of the experimental dies were compared with the dimensions of master die to get the linear dimensional discrepancy. The mean values were calculated and statistically analyzed using one way ANOVA and independent sample test.

Results: The obtained value were tabulated in which the mean and standard deviations were analysed using one way analysis of variance (ANOVA). Multiple range test by Tukey- Post Hoc test and Independent samples test was employed to identify the significant groups at 5% level. In this study, $P < 0.05$ was considered as the level of significance.

Conclusion:

- Type III gypsum material (Orthokal) showed the maximum linear dimensional accuracy when compared to other gypsum materials.
- Hand mixing and hand followed by vacuum mixing techniques was better and similar in reproducing the linear dimensional accuracy of the dies than the vacuum mixing of the gypsum material
- No statistically significant difference between polyvinyl siloxane and alginate impression material in the linear dimensional accuracy.

KEYWORDS

INTRODUCTION

Accurate duplication of teeth plays an essential role in the fabrication of fixed prosthesis^[1]. The ultimate success of a dental restoration depends mainly on accuracy, stability and completeness of die material, which undergo deformation during fabrication^[2]. An ideal die material should possess suitable important characteristics related to detail reproduction capability, minimum expansion, abrasion and compression resistances, low cost etc.^[3]. The selection of die material related to hardness and coating plays a vital role in the survival of die and also depends on ease of handling as well as the time required for fabrication^[4]. Due to the advent of elastomeric material, Restorative Dentistry has greatly simplified to produce accurate reproduction^[5]. Die material exhibit dimensional change while setting and hardening process^[6]. A number of die materials are available to satisfy the desirable qualities of die system^[7]. Products obtained from gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) materials are used extensively for the construction of die system. Accurate prosthesis depends on the type of gypsum materials poured into the impression^[8]. Gypsum is widely used for dental cast preparation for laboratory procedures^[9]. Dental gypsum, the main material in dentistry is available in five forms named as type I impression plaster, type II model plaster, type III dental stone, type IV high-strength dental stone and type V high-strength and high expansion dental stone. Dimensional accuracy of several gypsum materials has been discussed over the past decades. An important requirement of gypsum material relies on accurate reproduction of details, in which accuracies has an adverse effect on final restorations^[10]. The most commonly used gypsum die material is Type IV (high strength, low expansion) and Type V (high strength, high expansion) dental stones^[11]. Many dental practitioners and technicians select low cost gypsum materials in spite of physical and mechanical properties. Type IV harder dental stone and type V is regarded as a superior material since they produce more resistance to abrasion^[12]. Examples

of different gypsum materials are Fuji Rock, Pearl stone, Orthokal, Dental stone, Kalrock, Quick stone with varied dimensional properties. The process of manufacturing gypsum materials is carried out by dehydration process, which is done to remove the water constituents^[13].

In prosthodontic treatments, contaminated impression materials are considered as the main constituents to produce infection during dental procedures. Several impression materials such as Polyvinyl siloxane, alginate, reverse hydrocolloid, silicone etc. are used^[14]. The impression should be accurate to fabricate restoration related to ideal marginal fit, internal fit, interproximal contacts and occlusal contacts. Among the available impression material, non-aqueous elastomeric impression are considered to be the most accurate in terms of surface detail reproduction and are said to be dimensionally stable^[15]. Dimensional accuracy and stability are considered as the primary requisites of an impression material depending on properties like thermal contraction, polymerization shrinkage and presence of volatile by products etc.^[16]. Wettable characteristics of impression material also results in void formation in stone casts^[17]. Recently new technologies are introduced to improve the dimensional accuracy of gypsum materials such as computer aided design/computer aided manufacturing (CAD/CAM) to fabricate dental prostheses^[18]. Several scanning laser three dimensional digitizer tracks the X, Y and Z coordinates from the specimen with high precision and stores them on a surface with accurate and reliable characteristics thereby avoiding subjective errors^[19]. Also this uses several digitalized mechanical scanner to perform acquisition of data^[20]. Due to these advantages of digitalization, it is regarded as the best approach over conventional gypsum fabrication but we are focussing on the four gypsum materials with two impression materials under three mixing techniques to check the linear dimensional accuracy of the dies produced.

2. MATERIALS: Polyvinyl siloxane impression (PVS), Alginate impression (ALG), Type IV Gypsum (F-GC Fuji Rock) and (P-Pearl Stone), Type III Gypsum (O-Orthokal) and (S-Dental stone).

3. METHODOLOGY

3.1 Fabrication of Master Die:

To simulate a complete veneer crown preparation, a stainless steel ingot was machined to form a cylindrical shaped metal die in Fig.1 with height of 12mm and diameter of 13mm and 9mm at the cavosurface and occlusal end of die. The shoulder finish margin and convergence angle is considered as 1mm and 5 degree respectively.

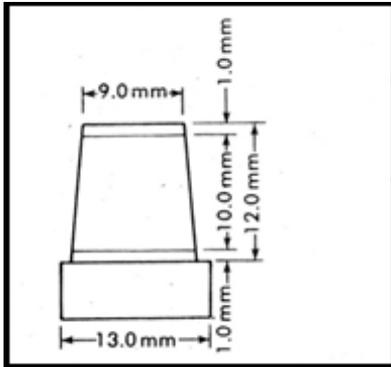


Fig.1 A cylindrical metal die

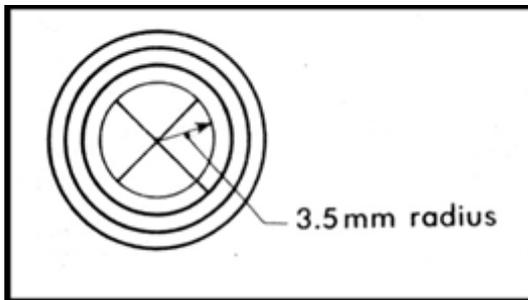


Fig.2 Occlusal surface of cylindrical die

The scribed perpendicular lines in Fig.2 intersect at the centre of occlusal surface with radius 3.5mm. The points at which the lines intersects the circle was used to measure the dimension of the occlusal surface. Two lines are scribed circumferentially on the axial wall 1mm below as well as above of occlusoaxial line angle and axio gingival line angle respectively. The various dimensions assumed from Fig.3, are as follows.

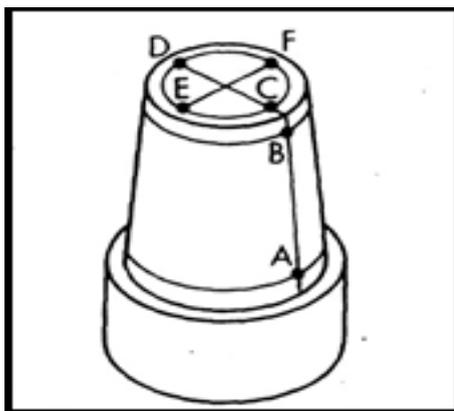


Fig 3. Schematic picture of cylindrical die

- (i) Dimension I (line AB) : Measurement of circumferential line along vertical axis
- (ii) Dimension II (line CD): Measurement of occlusal line intersecting at vertical axis

- (iii) Dimension III (line EF): Measurement of occlusal line perpendicular to dimension II.

3.2 Fabrication of Metal tray:

A metal tray was fabricated with uniform space of 3mm on the occlusal surface and axial walls in order to provide sufficient thickness for impression material.

3.3 Impression making Methods:

Two impression materials addition silicone elastomeric impression and irreversible hydrocolloids were used. In case of addition silicone material, mechanical and adhesive retention was used for tray fabrication. A 3mm thick metal coping was placed over the master die to provide space for the light body material. According to manufacturer's instructions, two pastes were hand mixed separately in which the uniform mix of light body consistency without streaks was poured into putty consistency and impression was prepared with proper orientation of tray under static load and then removed after setting. Each fabricated die produces an individual impression thus a total of 120 impressions was made using poly vinyl siloxane impression material.

Similarly, 120 impressions were prepared using irreversible hydrocolloid material shown in Fig.5 in which Mechanical retention was used for tray fabrication. Based on manufacturer's instructions, Alginate powder was proportioned and mixed with clear water.

3.4 Gypsum die fabrication:

The four gypsum materials are proportioned and mixed with water using three different techniques.

- (i) Hand mixed the water and powder for 60 seconds.
- (ii) Initially hand mixed for 15 seconds until the powder becomes wet and then mechanically mixed under 30 lb vacuum at 400 rpm in a vacu-vestor for 30 seconds.
- (iii) Completely vacuum mixed for 60 seconds at 30 lb vacuum and 400 rpm.

A total of 240 dies were made by pouring the impressions and were allowed to set for 1 hour. Figure 4-9 depicts the instruments used at different processing stages.

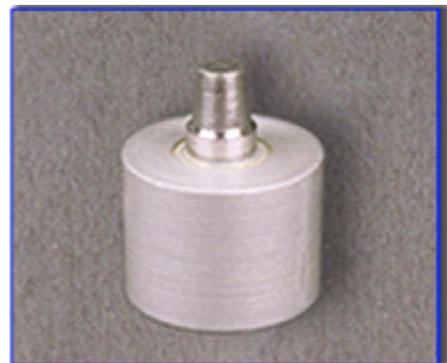


Figure 4 Master model simulating the Abutment tooth after preparation



Figure 5 Stock metal trays with perforation for mechanical retention



Figure 6 Stock metal tray with polyvinyl siloxane impression under static load

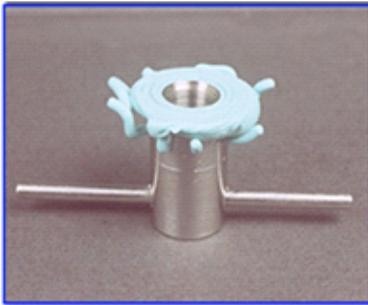


Figure 7 Putty impression material with spacer



Figure 8 Experimental die prepared using four gypsum material

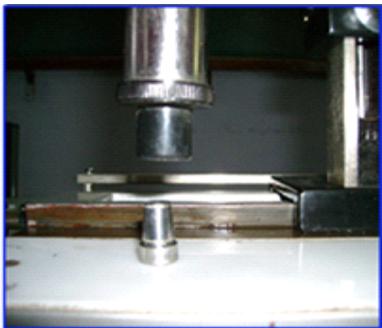


Figure 9 Dimensional measurement of the master model

3.5 Evaluation of dimensional accuracy of dies:

Initially, dies are measured using Traveling microscope (MIKRON) equipped with a metric micrometer and a vernier scale, in which the dimension was recorded from mean measurements taken under 50 X magnification. The mean and standard deviation of gypsum materials poured into impression materials using mixing techniques are reported in [7], in which an independent sample test was used to calculate the p value.

4. STATISTICAL ANALYSIS:

The mean and standard deviation of gypsum materials poured into different impression materials using different mixing techniques are tabulated in tables 1-5 and shown in figures 10-14.

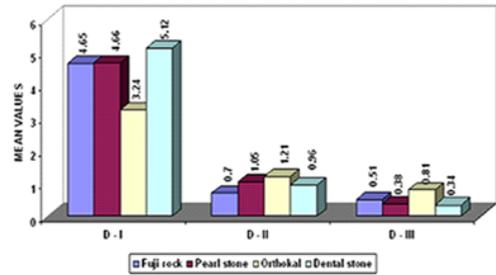


Figure 10 Dimensional variations of gypsum materials prepared by Polyvinyl siloxane

From the above table, the least mean value is provided by Orthokal, Fuji rock die material and Dental stone in Dimension I, II, and III respectively.

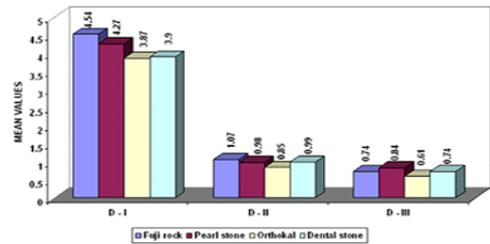


Figure 11 Dimensional variations of gypsum materials prepared by Alginate

When using Alginate impression material, the gypsum material Orthokal provides the least mean value in all the three dimensions.

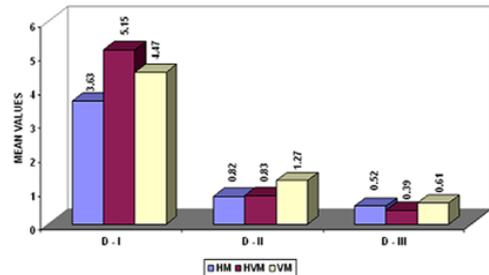


Figure 12 Dimensional variations between mixing techniques of Polyvinyl siloxane impression

In case of dimension I, II, Hand mixing offers the least mean value whereas in Dimension III, Hand mixing followed by Vacuum mixing provides the least mean value.

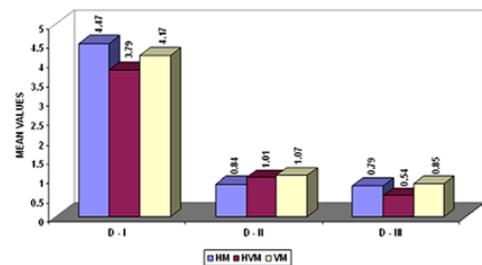


Figure 13 Dimensional variations between mixing techniques of Alginate impression

Hand Mixing followed by Vacuum Mixing provides the least mean value in case of Dimension I, III but in case of Dimension II, the least mean value is offered by Dimension II.

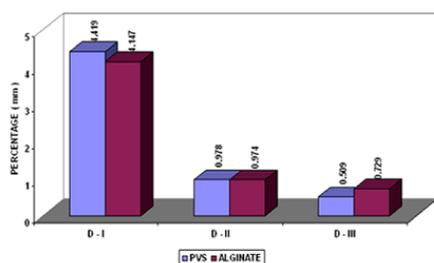


Figure 14 Dimensional variation between impression materials

Polyvinyl siloxane impression material provides the least value in dimension I, III whereas Alginate impression provides the least value in Dimension II. In each cases, independent sample test was used to calculate the p value.

5. DISCUSSION

Linear dimensional accuracy of impression materials plays a significant role in fixed prosthodontics. This study was mainly designed to identify the favourable gypsum material and mixing technique made from two impression materials with minimal linear dimensional discrepancy. The choice of impression material depends on the accuracy of detail reproduction, patient's comfort etc. During setting process, gypsum materials shows continuous growth and expansion^[21]. The change in dimensional accuracy depends on several factors such as gypsum and impression materials and its manipulation technique. This study considers the mixing of gypsum material in three different mixing techniques. The result of this study indicates that no single material is superior to other, in which statistical difference exists between them. Type III (Orthokal) and Type IV (Fuji rock) were considered as the closely approximated dies with respect to dimensions. Also statistical differences are possessed by type III (Orthokal) and hand mixing technique when used with polyvinyl siloxane especially in dimension I. No significant differences are observed statistically for both alginate and polyvinyl siloxane impression. Casts accuracy depends on water accuracy or gain while processing storing procedures^[22, 23]. Accurate casts are obtained by pouring impression materials immediately in the die material. Type III material exhibits high wear at marginal discrepancy while carving wax pattern^[24]. Hand mixing and hand followed by vacuum mixing produces the most accurate measurements when compared to master die in three dimensions, in which the maximum strength and hardness is possessed by hand followed by vacuum mixing than hand mixing alone. Alginate and polyvinyl siloxane restricts the dimension II and III due to its smaller length^[25]. Recently, several impression materials such as vinyl siloxanether^[26], vinyl polysiloxane, polyether impression system^[27] and plasma treated silicone impression^[28] that supports this methodology are used in the fabrication of gypsum die materials with different impression techniques such as Double-phase 2-step, Mono-phase, Double-phase 1-step^[29] etc. The impression materials like condensation silicone, polysulfidemercaptan, polyether handles the gingival tissues to produce structural information. The dimensional accuracy can also be predicted by adding suitable base materials to gypsum materials such as Laboratory plaster, Quick stone, Silky rock, Flow stone in which Quick stone is selected as the better material with minimal marginal error^[30]. The accuracy of Disinfected vinyl siloxanether is high when compared to vinyl polysiloxane and a polyether impression system.^[31] supports this methodology based on surface roughness and it proves that the alginate impression produces better results when compared to silicone impression whereas plasma treated silicone impression improves the wettability characteristics. But^[32] state that rubber silicone impression has greater accuracy than alginate, in which influence of delayed and repeat pours on alginate is discussed in^[33, 16]. Alginate impression material does not show any effect on its contact time while evaluating dimensional accuracy^[34]. Mechanically stable alginate impressions are obtained using custom made proportioning unit^[35]. Disinfected alginate impression with epimax solution is considered to be more effective against *Staphylococcus aureus* strain than sodium hypochlorite^[36]. Several techniques are introduced to improve the impression material accuracy. Dual arch impression technique provides less dimensional accuracy than multiple mix and and matrix impression system due to considerable distortion thereby not suitable for long span framework^[37]. The results that favour the above study is reported, where dual arch

technique produces superior accuracy but results in inaccurate dies due to lack in rigidity^[38]. Shake mixing of gypsum is proved to be an alternative when compared to hand and vacuum mixing due to its reduced time^[39]. Also^[40] states that no significant variation exists between dual arch and custom tray system. Mechanical mixing improves the compressive strength, elastic recovery of the alginate impression and considered to be more convenient than hand mixing^[41]. Accurate working cast is possible using tapered impression than squared and modified squared impression^[42]. Disinfectant solution exhibits shrinkage effects with respect to time due to the diffusion of various ions in alginate impression material^[43]. Condensation silicone offers low resistance to rip and increased distortion due to the instability of chemical ethyl alcohol. Polysulfidemercaptan produces better results related to capacity of elastomeric impression with limitation in sensitivity to temperature and humidity. Polyether requires a substantial force to remove from buccal cavity^[44]. In addition to that, several 3D technologies have also evolved to print and record the data digitally, which reduces the time consumption. Several gypsum materials with different colours^[45] and vinyl polysiloxane impression materials^[46] are also used in the fabrication of three dimensional systems. Each material has different properties and characteristics based on its advantages and disadvantages. Recent 3D CAM/CAM also possess several advantages^[47], comparable^[48] and disadvantageous characteristics^[49,50,51] when compared to conventional gypsum fabrication. In future, further modifications can also be done on Computer aided technology to improve its characteristics. Concentrations should be mainly on the volumetric change as well as the marginal discrepancy.

6. CONCLUSION

Based on the obtained results, the following conclusion are made

- Type III gypsum material (Orthokal) showed the maximum linear dimensional accuracy when compared to other gypsum materials.
- Hand mixing and hand followed by vacuum mixing techniques was better and similar in reproducing the linear dimensional accuracy of the dies than the vacuum mixing of the gypsum material
- No statistically significant difference between polyvinyl siloxane and alginate impression material in the linear dimensional accuracy.

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