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The Effect of Adding a Stone Base on the Accuracy of Working Casts Using Different Types of Dental Stone

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Abstract

Aim: Gypsum products are used for the preparation of stone casts of oral and maxillofacial structures and as important adjuncts to dental laboratory operations involved in the production of dental prostheses. The aim of this study was to determine the effect on the dimensional accuracy of a working cast of adding a stone base using different stone products.

Methods and Materials: A total of forty impressions of a mandibular dentoform were made. The impressions were dried with compressed air and stored at room temperature for 24 hours before pouring stone casts. The forty impressions were randomly divided into four groups of ten each. All forty impressions were poured once using one pre-weighed 140 Gm package of Silky Rock (SR) Type IV improved stone (Whip Mix Corporation, Louisville, KY, USA) per impression. All working casts and the die setups were prepared according to the manufacturer's recommendations for pin placement (M.R. Dual pin and sleeve). Four different types of dental stone (II, III, and IV) and Flow Stone (FS) were used as bases for the working models. They were mixed according to the manufacturer's recommendations.

The lower posterior teeth were flattened on the dentoform prior to taking the impressions. All were indexed using a mounted abrasive disc. Four teeth were selected as follows: 21, 28, 30, and 18. These represented A, B, C, and D landmarks, respectively. All measurements (five times for each specimen) were made with a Universal measuring microscope (Unitron Instruments, Inc., Bohemia, NY, USA). After the pre-sectioned measurements were recorded, the stone base was poured. A manual hand saw was used to section and fabricate removable dies for the mandibular landmarks A, B, C, and D. The dies were later seated and removed ten times to simulate the average amount of handling during laboratory procedures. Each die was carefully seated and measurements were made using the same technique as for the master model and unsectioned casts. Multivariate repeated measures analysis of variance (MANOVA) was used to test the difference in three different landmark distances (AB, AC, and AD) among the master model before and after sectioning of the working dies and among the four different base materials. Univariate analysis of variance (ANOVA) was conducted for each measurement, AB, AC, and AD to test the difference in landmark distances on the master model at pre sectioning and then at post sectioning using four different base materials. When there was a significant main effect ($p < .05$), the Student-Newman-Keul's (SNK) were used to test for pair wise comparison of means ($P<0.05$).

Results: The results of the MANOVA indicated there was a significant difference in three landmark measurements on the master model before and after sectioning of the working dies for the four different base materials ($F=6.60$, $p=0.0001$). In addition there was a significant difference in three landmark measurements on the master model at: (1) pre sectioning ($p=0.0001$), (2) between the master model and SR material ($p=0.0002$), (3) between the master model and Laboratory Plaster (LP) material ($p=0.0001$), (4) between the master model and Quick Stone (QS) material ($p=0.0001$), and (5) between the master model and FS material ($p=0.0001$).

Keywords: Working cast, dies, accuracy, dental stone, model, impression

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Introduction

Gypsum products are widely used in dentistry and especially in prosthodontics. These products have served the dental profession reliably for many years. They are used for the preparation of stone casts for oral and maxillofacial structures and as important adjuncts to the dental laboratory operations involved in the production of dental prostheses.[1,2]

Gypsum products used in dentistry are a form of calcium sulfate hemihydrate ($CaSO_4 \cdot 1/2\, H_2O$), which is classified into five types according to the American Dental Association (ADA) Specification #25.[3] The classification is as follows: impression plaster # (I); model plaster # (II); dental stone # (III); dental stone, high strength and low expansion # (IV); and dental stone, high strength, and high expansion # (V). Although these types have identical chemical formulas they possess different physical properties making each of them desirable for different purposes in dentistry.

The selection of the type of gypsum product for casts and dies is dependent on the purpose for which the replica is to be used. Accuracy and dimensional stability over time are properties of concern in fixed and implant prosthodontics. This explains why type IV dental stone is the predominant material used for making working casts and dies in the lost wax technique.[18]

Removable die systems are frequently used to facilitate the manipulation of dies during the laboratory phase of fixed prosthesis fabrication.[4,5] Contemporary die systems incorporate die pins into a die stone cast.[6] A stone base is then poured against the cast containing the die pins to create a special reference to hold the dies in the proper orientation. The die stone cast is then sectioned to provide removable dies. Upon removal the dies can be manipulated and then presumably be accurately placed back into the stone base in the precise original orientation. However, even using contemporary die systems, stone expansion inevitably affects die position.[7,8] The separation of individual dies from solid casts requires they be replaced in precisely the same position they occupied before removal. Both the setting expansion of the stone and the specific removable die system will affect die replacement accuracy. Expansion may create measurable shifts in die position.[9-10]

Conventional restorative dentistry demands dimensional accuracy in clinical and laboratory techniques especially in case of implants and long span fixed partial dentures. This explains why clinicians are often faced with sectioning and soldering implant-supported superstructures and long span fixed partial dentures (FPDs). These steps increase chair time and procedural costs and decrease clinical efficiency. One way to decrease the number of clinical steps involved is to improve the accuracy of working casts and die systems. Several concepts and techniques have been reported for working cast construction with removable dies.[11-14]

Reducing inaccuracies in a working cast can minimize laboratory errors and, thereby, decrease clinical time needed for insertion of a final restoration. The dentist and dental technician are faced with four variables that can affect the quality of the working cast during its fabrication and use:

- Expansion of the dental stone used.
- Ability to Accuracy of the impression procedure.
- Accuracy of the cast/die system.[14,15,16]
- Inherent setting precisely reposition the removable die.[17-18]

As we know, improved dental stone (IV and V) is normally used for the first pour of an impression, and Type III stone is typically used for the base pour. The latter has an inherent setting expansion,[19- 20] which makes it impossible to exactly reproduce the original tooth position in the working cast.

Some studies have evaluated the accuracy of the working cast and removable die systems[12,13] but none have evaluated the effect of the added stone base expansion on the accuracy of the working casts. The aim of the current study is to evaluate the effect of adding dental stone bases (with different types of dental stones, II, III, and IV) on the accuracy of the working cast.

Methods and Materials

The Master Model

A mandibular dentoform with plastic teeth (Figure 1) was used as a model (Ivorine, Dentoform M-PVR-1560, Columbia Dentoform Corporation, Long Island City, NY, USA).

The occlusal surfaces of the posterior teeth were surveyed using a Ney surveyor-parallelometer (Dental International, Bloomfield, CT, USA) marked and cut flat to make them parallel to each other. This enabled measurement on the microscope to be more precise. A mounted abrasive disc was used to make a cross shaped index on the occlusal surface of all posterior

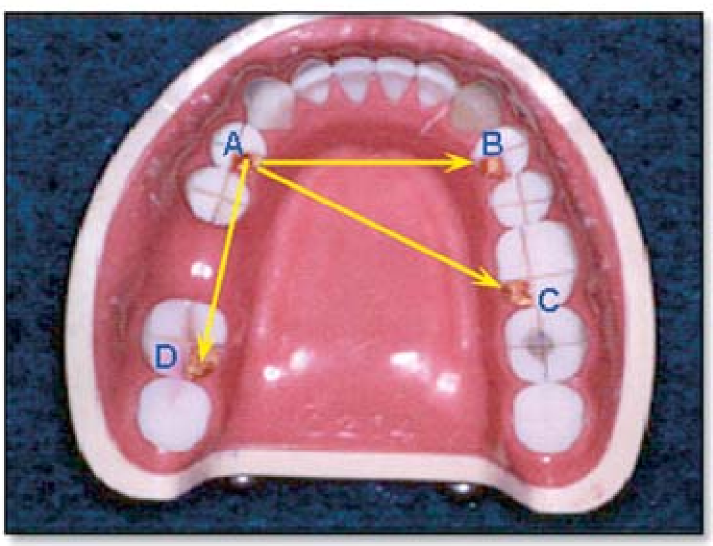


Figure 1. A photograph of the dentiform master model used in the current study.

teeth. One corner of that occlusal surface was used as a reference point to initiate the measurements.

Tooth numbers 21, 28, 30, and 18 (Figure 1) were selected as reference points. These represented A, B, C, and D landmarks, respectively. All measurements were made with a Universal measuring microscope (Unitron Instruments, Inc., Bohemia, NY, USA). This microscope is capable of recording measurements to within 1 micron in both mesio-distal and bucco-lingual directions.

Impression Technique

To make impressions of the dentoform, automatically mixed Extrude extra heavy body and Extrude wash polyvinyl siloxane impression material (Extrude™, Kerr Mfg. Corporation, Romulus, MI, USA) were used according to the manufacturer's instructions and placed in plastic impression trays (Spacer trays, size 20D, GC America, Alsip, IL, USA). The internal surfaces of the trays were uniformly painted with VPS™ tray adhesive (Kerr Mfg. Corporation, Romulus, MI, USA) and allowed to dry. The wash impression material was injected in and around the indices using an intraoral tip mounted on the mixing tip (Extrude, Kerr Mfg. Corporation, Romulus, MI, USA.). The impression tray with the extra heavy body Extrude impression material was then seated over the model with light finger pressure on incisors and last molar areas. The impression remained on the master cast for eight minutes. This was twice the manufacturer's recommendation time in order to compensate for polymerization at room temperature (25°C) rather than an intraoral temperature of 32°C in accordance with ADA Specification No.19.[11] Upon removal from the dentoform, the impression was carefully inspected for inaccuracies and voids and rinsed for ten seconds under tap water to simulate saliva removal.

A total of 40 impressions were made in this manner. Excess water was removed, the impressions were dried with compressed air, and stored at room temperature for 24 hours before pouring. This delay simulated the time required to send impressions to be poured by a commercial laboratory.

Working Cast Fabrication

The 40 impressions were randomly divided into four groups of ten each. The impressions were sprayed with debubblizer (Smoothex debubblizer, Whip Mix Corporation, Louisville, KY, USA) and allowed to sit for ten minutes.[21,22] Any excess was gently blown off with compressed air.

First Pour

All 40 impressions were poured once using one pre-weighed 140 Gm package of Silky Rock (SR) Type IV improved stone (Whip Mix Corporation, Louisville, KY, USA), per impression (Table 1a-b). Water was measured with a bottle top 20 mL dispenser with solid calibration accurate to + or – 0.2 %. As recommended by the manufacturer, a water-to-powder ratio of 32 mL to 140 Gm was used. The material was hand mixed for ten to 15 seconds then vacuum mixed with a Vac-U-Vestor machine (Whip Mix Corporation, Louisville, KY, USA) for 20 to 30 seconds at 425 rpm. Each impression was carefully poured using a paintbrush with slight vibration to ensure the flow of the stone into critical areas. The remaining stone was then slowly poured using a small spatula to place the stone into the impression. The poured impression was allowed to set for 24 hours. The casts were separated from the impressions, trimmed to a uniform height of 15 mm, and allowed to dry for 24 hours.

The Pindex® System

All working casts and the Pindex® die system (Coltène/Whaledent Inc., Cuyahoga Falls, OH, USA) were prepared according to the manufacturer's recommendations for pin placement (M.R. Dual pin and sleeve). That system has two long parallel sided stainless steel pins connected at the base. A single pin projects from the base. This pin fits into a drilled hole to provide a stabilizing and anti-rotation effect. The Pindex drill press unit is used to drill one pinhole for each removable section. Compressed air is used to clear all debris. The pins are cemented into the pre-drilled holes with cyanoacrylate adhesive (Permabond 102, Permabond, Somerset, NJ, USA) and allowed to dry. Stone separator medium (Super-sep, Kerr Mfg. Corporation, Romulus, MI, USA) was applied to the base and allowed to dry for ten minutes.

Table 1a. Materials used in the current study.

Gypsum Products	
Brand Name	**Manufacturer**
Laboratory Plaster, ADA Type II	Whip Mix, Louisville , KY , USA
Quick stone, ADA Type III	Whip Mix, Louisville , KY , USA
*Silky Rock, ADA Type IV	Whip Mix, Louisville , KY , USA
Flow Stone	Whip Mix, Louisville , KY , USA
* ADA certified gypsum materials	

Table 1b. Mixing procedure.

Gypsum Product	Water/Powder Ratio ml/g	Method of Mixing	Mixing Time (Seconds)	
			Hand	Vacuum
Laboratory Plaster	45/100	Hand & Vacuum	60	30
Quick Stone	28/100	Hand & Vacuum	60	30
Silky Rock	23/100	Hand & Vacuum	60	30
Flow Stone	22-24/100	Hand & Vacuum	00	00

The metallic sleeves were placed in the metallic dowels before the base was poured. The tips of the dowels were covered with a small piece of wax before pouring the base (Utility wax-round strips, Henry Schein Inc., Melville, NY, USA).

Second Pour (The Base)

Four different types of dental stone (II, III, and IV) were used as bases (Tables 1a-b) for the working models. They were mixed according to the manufacturer's recommendations using hand mixing first followed by mechanical spatulation with a Vac-U-Vestor machine.

A new stone material was included in the study (Flow Stone, Whip Mix Corporation, Louisville, KY, USA) which is a flowable material that can be poured without the use of vibration.

A rubber base mold (Model Former, Columbia Dentoform, Long Island City, NY, USA) was used for making bases for the working casts. All bases were trimmed to have a uniform height of 18 mm after using a plastic ruler to measure the height. All casts were sectioned with a handsaw 24 hours after the base had set.

Landmark A was used as the starting point and zeroed in X, Y axes. The X and Y coordinates were measured by centering the selected corner using the microscope objective cross hairs. The measurements were recorded as follows (Figure 2):

The model was removed and replaced on the measuring table and the measurement was repeated five times for each specimen.

Pre-sectioned Solid Cast Measurement

The pre-sectioned sample casts were measured in the same manner as the master model at A, B, C, and D.

Post-sectioned (with base) Cast Measurement

After the pre-sectioned measurements were recorded, the base was poured. A manual hand saw was used to section and fabricate removable

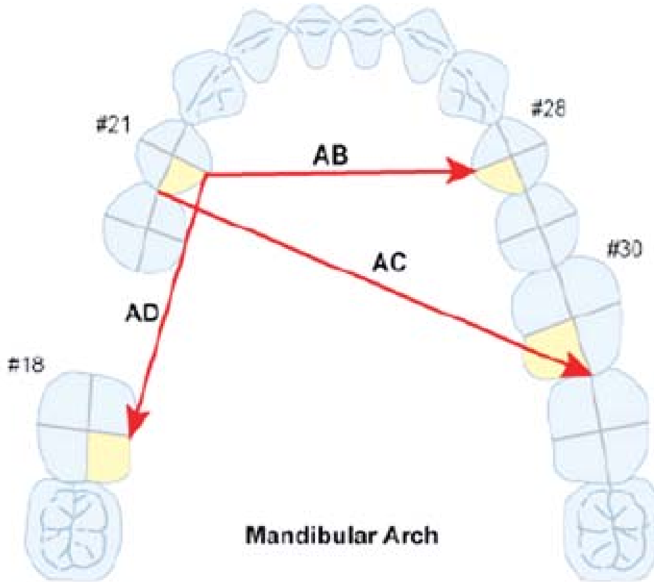


Figure 2. Measurements used in the study.

- **AB** measurement from the buccal wall of the distolingual corner of tooth #21 to the buccal wall of the distolingual corner of the tooth #28.
- **AC** measurement from the buccal wall of the distolingual corner of tooth #21 to the buccal wall of the distolingual corner of the tooth #30.
- **AD** measurement from the mesial wall of the distolingual corner of tooth #21 to the mesial wall of the distolingual corner of the tooth #18.

dies for the mandibular landmarks A, B, C, and D. Loose debris was removed from the dies and cast using a soft brush and compressed air. The dies were carefully trimmed to prevent binding. The dies were later seated and removed ten times to simulate the average amount of handling during laboratory procedures. The die was carefully seated and measurements were made using the same technique as for the master model and un-sectioned casts.

Statistical Analysis

Multivariate repeated measures analysis of variance (MANOVA) was used to test the difference in three different landmark distances (AB, AC, and AD) on the master model before and after sectioning of the working dies and when the four different base materials were added. Statistical contrasts were used to test the significance of the master model and pre and post section with four different base materials.

Univariate analysis of variance (ANOVA) was conducted for each measurement, AB, AC, and AD to test the difference in landmark distances on the master model, pre sectioning, and post sectioning (using four different base materials). When there was a significant effect ($p<.05$), the Student-Newman-Keul's (SNK) was used to test for pair wise comparison of means. All hypothesis testing was conducted at $\alpha=0.05$. The same analysis was conducted using the coefficient of variation of the distance measures rather than the mean of the measurements (the coefficient of variation is defined as the ratio of the standard deviation and the mean times 100). The Confidence Interval (CI) and the Margin of Error were also used. The CI was used to determine the best stone material to use as a base material. The CI=mean ± 2.262 (Std. error) in a 95% CI. If the lower confidence limit (LCL) and upper confidence limit (UCL) are both positive, then the mean difference is significantly different from zero.

Results

The results apply to the measurement of all casts and the master model (in µm) for the four different base materials tested are shown in Table 2 and Figures 3a, b, and c.

The results of the MANOVA indicated there was a significant difference in three landmark measurements on the master model before and after sectioning of the working dies for the four different base materials (F=6.60, p=0.0001). In addition there was a significant difference in three landmark measurements on the master model and pre sectioning (F=23.76, p=0.0001), between the master model and SR material (F=7.71, p=0.0002), between the master model and Laboratory Plaster (LP) material (F=8.18, p=0.0001), between the master model and Quick Stone (QS) material (F=12.85, p=0.0001), and between the master model and Flow Stone (FS) material (F=14.82, p=0.0001). Also, there was a significant difference in three landmark measurements between pre sectioning and SR material (F=9.42, p=0.0001), between pre sectioning and LP material (F=8.85, p=0.0001),

Table 2. Measurements for all casts and master model (in µm).

	AB	AC	AD
Master Model	35505.8	42946.0	27269.8
Pre sectioned	35136.6	42200.5	27812.4
Silky Rock Base	34947.2	42612.2	27317.7
Lab. Plaster Base	35075.2	42823.0	27467.1
Quick Stone Base	34790.2	42507.9	27337.4
Flow Stone Base	34690.7	42538.0	27290.9

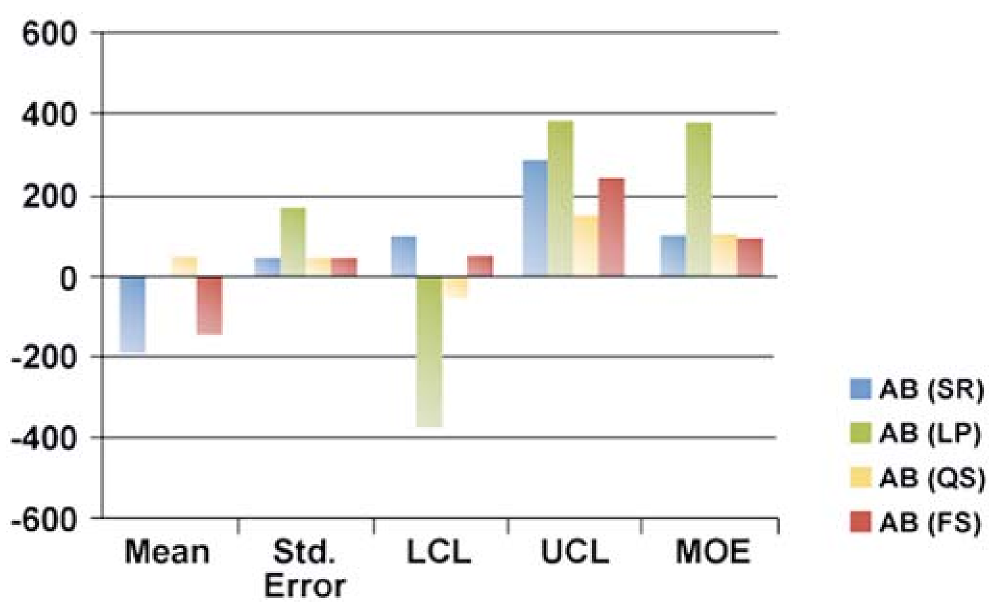


Figure 3a. CI and margin of error for the AB landmark.

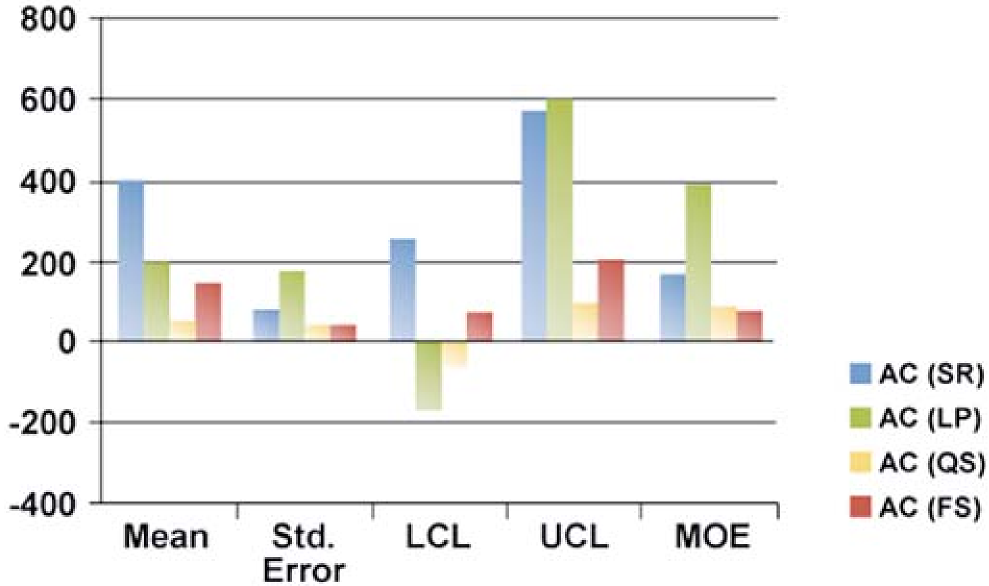


Figure 3b. CI and margin of error for the AC landmark.

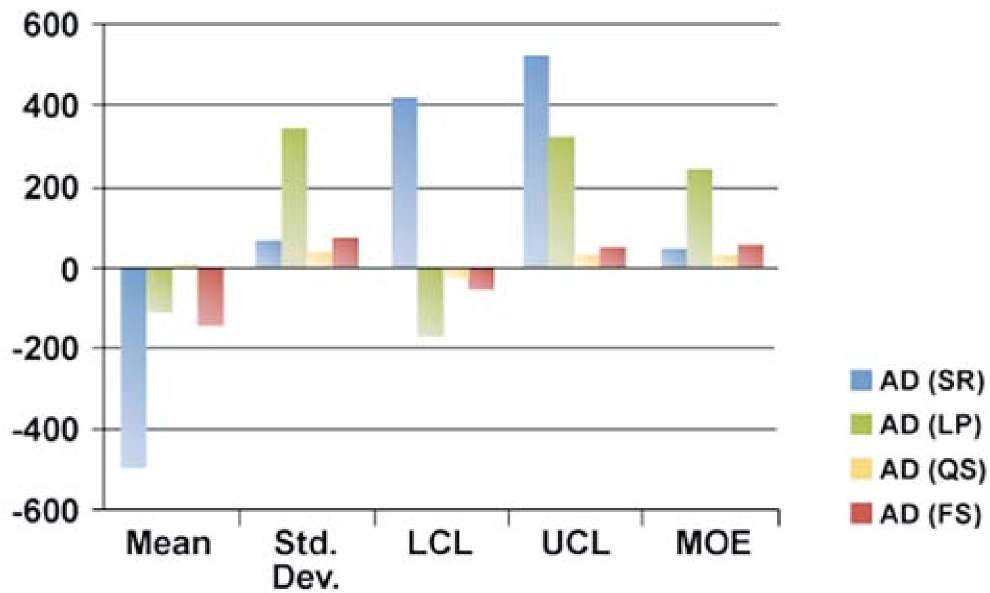


Figure 3c. CI and margin of error for the AD landmark.

Table 3. Confidence interval and margin of error for all base materials used.

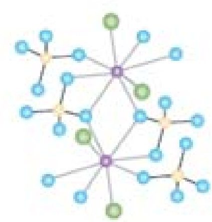
Variable	Mean	Std. Dev.	Std. Error	LCL	UCL	MOE
AB (SR)	-189.32	137.06	43.35	91.26	287.38	98.06
AC (SR)	411.76	226.86	71.74	249.48	574.04	162.28
AD (SR)	494.66	69.68	22.04	444.81	544.51	49.85
AB (LP)	6.38	526.38	166.46	-370.15	382.91	376.53
AC (LP)	209.06	541.83	171.34	-178.51	596.63	387.57
AD (LP)	87.20	359.02	113.53	-169.61	344.01	256.81
AB (QS)	45.80	141.13	44.63	-55.15	146.75	100.95
AC (QS)	-12.32	111.46	35.24	-67.39	92.03	79.71
AD (QS)	7.82	45.99	14.54	-25.07	40.71	32.89
AB (FS)	-140.88	133.71	42.28	45.24	236.52	95.64
AC (FS)	138.02	101.30	32.03	65.57	210.47	72.45
AD (FS)	4.04	81.34	25.72	-54.14	62.23	58.18

between pre sectioning and QS material (F=7.90, p=0.0002), and between pre sectioning and FS material (F=9.96, p=0.0001). When the coefficient of variations (CV) were used, there was a significant difference in the CV of the three landmark measurements among the master model, before and after sectioning of the working dies, the four different base materials (F=6.68, p=0.0001). In addition there was a significant difference in the CV of the three landmark measurements among master model and pre sectioning (F=14.58, p=0.0001), between master model and SR material (F=27.50, p=0.0001), between master model and LP material (F=30.88, p=0.0001), master model and QS material (F=27.87, p=0.0001), and master model and FS material (F=27.85, p=0.0001). Also, there was a significant difference in three landmark measurements between pre sectioning and SR material (F=3.88, p=0.0142), between pre-sectioning and LP material (F=4.49, p=0.0071), between pre sectioning and QS material (F=4.14, p=0.0104), and between pre sectioning and FS material (F=3.52, p=0.0211).

When only the base materials were considered, the results indicated there were no significant differences in the means of AB, AC, and AD among the four base materials except the case where there was a significant difference in mean of AB between LP and FS.

As indicated in the Table (3), AB (QS), AC (QS), and AD (QS) showed they are the best material in term of the CI (being inconclusive) with low margin of error.

Discussion



The expansion of stone has been attributed to the growth and development of the crystalline hemihydrate lattice from the supersaturated solution and the accompanying out thrust of the gypsum crystals during setting.[23] 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.

Manufacturers of such products have introduced modifications and refinements in a general effort to minimize expansion, but the exacting demands of modern dentistry have become increasingly intolerant of any imprecision, especially with respect to implant prosthodontics and multiple abutment prostheses. Thus, in addition to a careful choice of dependable stones, it is imperative to use techniques or systems that will consistently lead to reproducible and faithfully accurate results.

The pre-sectioned cast to master model measurement represents the magnitude of movements of landmarks under the impression-making and cast-pouring conditions of this investigation.

It is well known gypsum products have some degree of expansion during setting. SR has an expansion of 0.16%. The measurements show expansion for the same side (in mesio-distal direction, AD landmark), but the cross arch measurement (bucco-lingual direction, AB and AC landmarks) showed a contraction. This might be related to the expansion of the impression material inside. There was a difference in the landmark measurements among all the pre-sectioned (solid) casts that could be related to the impression material. In the impression tray the material is relatively free to expand mesiodistally, whereas buccolingual expansion is restricted by the walls of the tray. The same influence pertains to the poured stone inside the impression. Making the impressions were subject to this phenomenon even though all the conditions were standardized and the investigation attempted to minimize the errors of the impression procedure by using the auto-mix procedure.

Another explanation for the differences in the percentage of the expansion might be attributed to variations in the pre-packaged batches of SR. Most of the variability of landmark measurement existed in the solid cast (-761.44 µm for AB, -745.54 µm for AC and +542.56 µm for AD). This was possibly due to the variations in the content of the additives in the pre-packaged SR from one pack to another. These findings do not match a study conducted by Aramouni and Millstein.[12]

Although, the results of the MANOVA indicated there was a significant difference in three landmark measurements among master model and pre-sectioning ($F=23.76$, $p=0.0001$). AB and AC landmark measurements also showed there was a contraction of the solid cast “SR” (range - 369.24 to -761.44 µm for AB and - 332.04 to -745.54 µm for AC). The measurements also showed an expansion for AD landmark measurements (+17.08 to +542.56µm) so the range between expansion and contraction (-761.44 to +542.56 µm) was 1304 µm. These results imply if the arch is crossed with a one piece fixed partial denture, the prosthesis would require sectioning and soldering unless these contraction values are compensated by expansion of the added base. Fortuitously in case of the unilateral or straight side (linear) FPD there was an expansion of the solid cast.

Comparison of the values of the master model to post-sectioned cast provides an analogous comparison of a patient to the working cast which is the overall measure for accuracy of each combination of materials used. In addition there was a significant difference in three landmark measurements on the master model and all post-sectioned casts with different materials.

According to this study, there was a contraction for AB and AC landmark measurements for all the materials and an expansion for AD landmark measurements. These dimensional changes were consistent for all casts measured. The degree of changes seemed to be greatly influenced by the values of the solid cast. The most representative system was with the LP base. The value for landmark AB was 35136.6 compared to 35505.8 µm. For landmark AC, the value was 42823.0 µm compared to 42946.0 µm.

For AD landmark FS base was the most representative for master model 27290.9 compared to 27269.8 µm.

The SR base material demonstrated the range of change was -558.6 µm to +47.9 µm or 606.5 µm. With LP the range was -430.6 µm to +197.3 µm or 627.9 µm. QS bases demonstrated the range to be -716.6 µm to +67.6 µm or 784.2 µm, while for FS bases the range was -674.2 µm to +17.08 µm or 691.28 µm. These absolute values showed the difference between the maximum expansion and contraction of the landmark measurements.

The differences that resulted from the analysis of the pre-sectioned to the post-sectioned casts define the specific direction and magnitude of the movement of the sectioned dies.

These values can be obtained by subtraction of the landmark measurements after sectioning from the pre-sectioned (solid) cast.

Table 4. The differences in direction and magnitude of the movement of the sectioned dies that resulted from the analysis of the pre-sectioned to the post-sectioned casts.

Landmark	QS	SR	LP	FS
AB	+ 45.84 µm	- 189.4 µm	- 6.4 µm	-140.9 µm
AC	- 12.34 µm	+411.74 µm	+ 209.04 µm	+ 138 µm
AD	+7.8 µm	- 494.66 µm	- 87.16 µm	+ 4.02 µm

As shown in Table 4, AB landmark measurements indicated all materials experienced contraction except for QS, which showed expansion. AC landmark measurements showed an expansion for most materials except for QS. The AD landmark measurements QS and FS showed an expansion while SR and LP showed a contraction.

As shown in Table 5, the range of the differences for post-sectioned (from pre-sectioned) cast landmarks measurement (between maximum expansion and maximum contraction) were 235.24 µm for AB, 424.08 µm for AC and 502.46 µm for AD as absolute values between expansion and contraction of the added bases. The range of difference between the post-sectioned master model was (-815.1 µm, FS for AB) to (+197.3 µm, LP for AD) =1012.4 µm. While in the pre-sectioned master model, it was (-761.44 µm, QS for AB) to (+542.56 µm, SR for AD)=1304.0 µm. In the pre-sectioned–post sectioned cast (+411.74 µm, SR for AC) to (-494.66 µm, SR for AD)=906.40 µm. The differences (the absolute values between the maximum expansion and contraction) among the materials are:

- For SR: -494.66 to +411.74 = 906.4 µm.
- For LP: -87.16 to +209.04 = 296.2 µm.
- For QS: -12.34 to +45.84 = 58.18 µm.
- For FS: -140.9 to +138 = 278.9 µm.

Table 5. The differences between post-sectioned and pre-sectioned cast landmarks.

Landmark	Range
AB	235.2 µm
AC	424.08 µm
AD	502.46 µm

Table 6. The differences between maximum expansion and contraction among the materials tested.

Materials tested	Range in µm
QS	58.18 µm
SR	906.4 µm
LP	296.2 µm
FS	278.9 µm

As shown in Table 6 for SR (Type IV, with 0.9% of expansion according to the manufacturer) base material, the maximum changes existed 906.4 µm compared to the rest of the materials; this could be explained in two ways. One explanation for this could be due to the small spaces between the gypsum particles high internal stresses exist between the particles and once the solid cast was sectioned these stresses were relieved. Another explanation might be an incomplete setting of the stone material and some changes continued to occur until the material was completely set.

For LP (Type II regular set, with 0.2% expansion rating by the manufacturer) and FS (Type IV, with 0.08% of expansion rating by the manufacturer), the two materials demonstrated very similar changes with 296.2 µm and 278.9 µm, respectively. These values were less for laboratory plaster than for SR. This could be explained by the larger spaces between the gypsum particles in laboratory plaster. Thus, internal stresses are less than SR, and they did not show large changes. It is also possible the material might not have completely set before sectioning. This raises the question of whether the fast set type stone would routinely yield less change since the material set quickly and may set completely before sectioning.

The amount of change for FS was found to be slightly less or equal to LP. These values are less than those for SR which is still considered Type IV gypsum. This material is a flowable material, and this may lead to less friction between the gypsum particles of the material and to less change on the set material. QS (Type III, with 0.16% of expansion rating by the manufacturer) showed a 58.18 µm change which was the minimum among all the other base materials. The only explanation for this result is the material may have completely set before the solid cast was sectioned.

To evaluate if there was any statistical difference among the base materials we used the CV since it is the most accurate. The CI shows the values of the mean and the standard of deviation at the same time. The CV indicated no statistical difference among the base materials. Clinically, there is a potential problem since the periodontal ligament (with an average width of 100 µm) can only compensate for a poor fit by a slight movement. In addition this movement only compensates for a horizontal discrepancy.

If we focus only on the changes that occurred by adding the base material (between the maximum expansion and contraction values) and assume the solid cast is an excellent representation of the master cast, then the following resulted. QS showed an average change of 58.18µm. FS and LP were somewhat greater at 278.9 µm and 296.2 µm. respectively, whereas the greatest changes were noted with SR (906.4 µm). As indicated in the Table (3), AB (QS), AC (QS), and AD (QS) showed they are the best material in term of the CI (being inconclusive) with a low margin of error.

Conclusion

Within the limitations of the study design and the materials used, the following conclusions can be made:

1. There was a difference in the average measurements of the solid cast for the different landmarks.
2. The difference in the measurements between the master model and LP was the smallest, particularly in AB and AC landmarks.
3. There was no significant difference in measurements among the four materials.
4. As shown in the Table 3, the results of the CI indicated AB (QS), AC (QS), and AD (QS) provided the best material in terms of resulting in smallest margin of error in measurements.
5. Overall we found QS to be the best material for pouring bases.

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