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Terence A. Imbery, Joshua Nehring, Charles Janus and Peter C. Moon

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Terence A. Imbery, DDS; Joshua Nehring, BS; Charles Janus, DDS, MS; Peter C. Moon, PhD

ABSTRACT

Background. The authors conducted a study to determine if two irreversible hydrocolloid impression materials (Cavex ColorChange, Cavex Holland BV, Haarlem, Netherlands; Jeltrate Plus Antimicrobial Dustless Alginate Impression Material, Dentsply Caulk, Milford, Del.) stored for five days were dimensionally accurate.

Methods. The authors modified Ivorine teeth (Columbia Dentoform, Long Island City, N.Y.) on a Dentoform model (1560 series model, Columbia Dentoform) to allow measurements of tooth and arch width. They made impressions and generated casts immediately and at five additional times. They recorded tooth and arch widths on the casts and compared the measurements with those for the standard model.

Results. Compared with measurements for the model, the greatest measured difference in casts was 0.003 inches for Cavex ColorChange (extended-pour alginate) and 0.005 inches for Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate). The percentage of dimensional change ranged from −0.496 to 0.161 percent for the extended-pour alginate and from −0.174 to 0.912 percent for the conventional alginate.

Conclusions. Results of analysis of variance and paired *t* tests indicated that when generated immediately and at day 5, casts produced from both impression materials were not statistically different from the standard model ($P < .05$).

Clinical Implications. When stored properly, both alginate materials can produce accurate impressions at day 5 for diagnostic casts and for fabrication of acrylic appliances.

Key Words. Alginate; impression; accuracy; syneresis; imbibition.
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ARTICLE 2

Diagnostic casts provide valuable information for diagnosis, treatment planning, patient education and consultation with other dental care providers. Clinicians also can use diagnostic casts for fabrication of custom trays and removable prostheses. The vast majority of diagnostic casts are produced by making an impression with an irreversible hydrocolloid (or alginate) and casting it in a type III gypsum product.[1]

Alginate impression materials consist of a powder that when mixed with water forms a fast-setting gel. The reactive constituents of alginates are sodium or potassium salts of alginic acid and calcium sulfate that when mixed with water form a sol. The calcium replaces the monovalent sodium and potassium cations, allowing cross-linking of alginic salts and resulting in gel formation. Manufacturers add filler and smaller amounts of other proprietary ingredients to control consistency, setting time, elasticity, strength and dimensional stability.

Compared with nonaqueous materials (such as polyethers and addition and condensation silicones), alginates are inexpensive. However, alginate impressions may undergo expansion by absorbing water (imbibition) or shrinkage by losing water through evaporation and continued reaction of the sol

Dr. Imbery is an assistant professor, Department of General Practice, School of Dentistry, Virginia Commonwealth University, Lyons Building, 4th Floor, Room 406, 520 N. 12th St., PO Box 980566, Richmond, Va. 23298-0566, e-mail "taimbery@vcu.edu". Address reprint requests to Dr. Imbery.
Mr. Nehring is a third-year dental student, School of Dentistry, Virginia Commonwealth University, Richmond.
Dr. Janus is an associate professor, Department of Prosthodontics, School of Dentistry, Virginia Commonwealth University, Richmond.
Dr. Moon is an associate professor, Department of General Practice, School of Dentistry, Virginia Commonwealth University, Richmond.

(syneresis). Imbibition, syneresis and water evaporation may result in the production of inaccurate casts.

For decades, dental professionals were taught that casts produced from alginate impressions must be generated immediately or within 12 minutes after the impression is removed from the patient's mouth.[1-12] Researchers have recommended immediate pouring of a gypsum product into the impression because there is no adequate storage method for any hydrocolloid impression material.[8,10] Furthermore, Rudd and colleagues[5] and Phoenix and colleagues[6] reported that clinicians should never immerse alginate impressions in a liquid or wrap them in a damp paper towel. According to Morrow and colleagues,[3] the most common error made in using alginate impression materials is not pouring the gypsum product into the impression immediately. Wrapping an impression in a wet paper towel is not an acceptable alternative to pouring the gypsum product immediately.[5,6] Eissmann and colleagues[4] reported that the alginate imbibes moisture from the paper towel, and uneven weight or pressure from the towel may cause distortion. Morrow and colleagues[3] and Eissmann and colleagues[4] described a method of fabricating a humidor in which to store alginates for as long as 30 minutes before generating a cast from the impression.

The alginate impression material used at Virginia Commonwealth University School of Dentistry, Richmond, is Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (Dentsply Caulk, Milford, Del.). After disinfecting an impression, students in the dental school typically wrap the impression loosely in a damp paper towel when they are unable to generate a cast immediately. When one of us (T.A.I.) asked instructors to cite the scientific evidence that supports this protocol, they were unable to provide substantiating proof other than to cite this as conventional practice. Newer irreversible hydrocolloids are marketed with claims of dimensional stability and accuracy of as long as five days. One such material is Cavex ColorChange (Cavex Holland BV, Haarlem, Netherlands), which features a three-step chromatic shift from the beginning of mixing (blue) to placement in the tray (pink) to complete setting (white).

The purpose of this study was to determine if the two impression materials produce dimensionally accurate casts when the clinician delays pouring the gypsum product into the impression for up to five days by using specified storage conditions.

MATERIALS AND METHODS

We modified a Dentoform model (1560 series model, Columbia Dentoform, Long Island City, N.Y.) by mechanically embedding a portion of ball bearings 3 millimeters in diameter in the facial surfaces of teeth nos. 3 and 14 and a single ball bearing in the lingual surface of tooth no. 14 and by using acrylic resin for retention. The measured distance from the greatest convexity of the ball bearing on the facial surface of tooth no. 3 to the greatest convexity of the ball bearing on the facial surface of tooth no. 14 was 2.345 inches, and we designated it as the arch width. The measured distance from the greatest convexity of the ball bearing on the facial surface of tooth no. 14 to the greatest convexity of the ball bearing on the lingual surface was 0.497 inches, and we designated it as the tooth width.

One of us (T.A.I.) placed a light-body impression material (Aquasil Ultra LV Regular Set Smart Wetting, Dentsply Caulk) in the gingival embrasures of the model to prevent locking and subsequent tearing of the alginate impression materials. He added four columns of Triad Denture Base material (Dentsply Trubyte, York, Pa.) to the model to create stable stops for the impression trays; this also allowed the operator (J.N.) to seat the impression trays in an accurate and reproducible position (Figure 1).

The operator (J.N.) modified large perforated maxillary trays (COE Spacer Trays, GC America, Alsip, Ill.) by adding dental impression compound (Kerr, Orange, Calif.) to the palatal and posterior border areas of the trays. In addition to confining the impression material to the tray, the dental impression compound enabled the operator to place a uniform 6 mm of impression material in the palatal vault. He applied proprietary tray adhesives for the two impression materials and allowed them to dry for five minutes before making the impressions.

The operator (J.N.) weighed the impression materials (31 grams for Jeltrate Plus Antimicrobial Dustless Alginate Impression Material [conventional alginate] and 30 g for Cavex ColorChange [extended-pour alginate]) and stored them in airtight specimen jars. Following the

ABBREVIATION KEY. ADA: American Dental Association.

Figure 1. Dentoform model (Columbia Dentoform, Long Island City, N.Y.) with embedded ball bearings and stops made of Triad Denture Base Material (Dentsply Trubyte, York, Pa.), which allowed the tray to be seated in a reproducible manner.

manufacturers' recommendations, he placed the proper amount of tap water in a mixing bowl and added the impression material to it. He then folded the powder into the water and mixed it by hand for five seconds, followed by vacuum mixing (Twister Evolution Pro, Renfert, Hilzingen, Germany) for 30 seconds at 400 revolutions per minute and 30 pounds per square inch of vacuum. The operator loaded the impression materials in the trays and wiped a small amount of material over the occlusal, facial and lingual surfaces of the modified teeth. He seated the trays on the model until they rested firmly against the stops made with the Triad Denture Base material.

Water bath. The operator (J.N.) placed a 1-kilogram weight on the impression tray and placed the entire assembly in a water bath (Teledyne Hanau, Buffalo, N.Y.) at 37°C. The conventional alginate remained in the water bath for three minutes, while the extended-pour alginate remained for 15 seconds after it changed from pink to white. He removed the assemblies (model and tray) from the water bath, removed the trays from the models and lightly shook the trays to remove excess water.

Storing impressions. The operator stored the impressions that were not poured immediately in plastic zipper storage bags at room temperature (23°C). Before storage, he wrapped the conventional alginate impressions in damp paper towels by using 12 milliliters of tap water per towel to simulate the protocol taught at our institution. Following the manufacturer's instructions, he did not wrap the extended-pour alginate impressions in paper towels but simply sealed them in plastic zipper storage bags.

Casting impressions. The operator cast the impressions via the single-pour technique in a type III gypsum product (Microstone, Whip Mix, Louisville, Ky.) by vacuum mixing 140 g of powder (prepackaged) with 40 mL of tap water. He vibrated the stone gently into the impression, beginning at tooth no. 1 and advancing along the arch to avoid incorporating voids before filling the palate. The operator placed the remaining stone in a large model former (Wholesale Dental Manufacturing & Supply, Tustin, Calif.), inverted the impression and placed it into the model former. He cast the impressions immediately after removal from the model and at five additional periods (day 1, day 2, day 3, day 4 and day 5). The operator stored the gypsum casts in a humidor for 45 minutes before separating the cast from the tray. He allowed all casts to dry for 24 hours before examining and measuring them. He made five samples of each material from each period for a total of 60 casts.

Recording measurements. The operator recorded tooth and arch widths to the nearest 0.001 inch by measuring the greatest distance between convexities of the ball bearings or their cast reproductions. He used a dial caliper (model 505-637, Mitutoyo America, Aurora, Ill.) to measure the tooth and arch widths, ensuring that the caliper remained parallel to the horizontal plane of the model. The same operator made all impressions, casts and measurements. To reduce human error and increase precision, the operator measured and recorded both arch and tooth widths three times for each cast to calculate the mean amount and percentage of dimensional change.

Statistical analysis. We used a repeated-measures mixed-model analysis to assess the measured values for each material on each day. The assessment included effects for materials, for time and for the two-way interaction between materials and time. We performed separate analyses for arch width and tooth width by using statistical software (JMP version 8, SAS Institute, Cary N.C.). We tested differences between the estimated means and the true values at $\alpha = .05$.

RESULTS

Table 1 presents the mean tooth widths, 95 percent confidence intervals, P values (compared with the standard model) and percentage of dimensional change, and Figure 2 shows the mean tooth widths. Similarly, Table 2 and Figure 3 show the results for arch width. As Figures 2 and 3 indicate, the extended-pour alginate tended to produce slightly smaller casts than the standard model, while the conventional alginate produced slightly larger casts.

Casts made from the conventional alginate yielded tooth widths that were significantly different from those of the model when generated on days 3 and 4, while arch widths were significantly different on day 3 only. Casts made from the extended-pour alginate yielded tooth widths that were significantly different from those of the standard model only when generated on day 1 and arch widths that were significantly different on days 1 and 2. When generated immediately and at day 5, casts produced by both impression materials were statistically accurate with regard to arch and tooth width compared with the model.

Table 3 (page 37) shows the comparison between the two impression materials.

DISCUSSION

Impression materials should be accurate and remain dimensionally stable until cast in a gypsum product. Accuracy is the ability to reproduce a true measured value, and dimensional stability is the

TABLE 1

Tooth width characteristics.

DAY	MEAN TOOTH WIDTH, INCHES*	95% CI†	*P* VALUE‡	PERCENTAGE OF DIMENSIONAL CHANGE	NO. OF SPECIMENS WITHIN 0.003 INCHES OF STANDARD MODEL MEASUREMENTS
Cavex ColorChange§					
0	0.498	0.495-0.500	.982	0.161	5
1	0.495	0.492-0.497	.011	–0.496	1
2	0.496	0.493-0.498	.124	–0.228	4
3	0.495	0.493-0.498	.066	–0.309	4
4	0.497	0.494-0.499	.387	–0.054	5
5	0.497	0.495-0.500	.619	0.040	3
Jeltrate Plus Antimicrobial Dustless Alginate Impression Material¶					
0	0.496	0.494-0.499	.183	–0.174	4
1	0.499	0.496-0.501	.442	0.362	5
2	0.499	0.496-0.501	.506	0.335	2
3	0.501	0.498-0.503	.019	0.778	2
4	0.502	0.499-0.504	.005	0.912	1
5	0.500	0.498-0.503	.051	0.671	3

* Standard error of the mean = 0.00126.
† CI: Confidence interval.
‡ Comparing estimated mean with actual tooth width of 0.497 inches. A *P* value < .05 indicates that the mean is significantly different from the actual tooth width.
§ Cavex ColorChange impression material (extended-pour alginate) is manufactured by Cavex Holland BV, Haarlem, Netherlands.
¶ Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate) is manufactured by Dentsply Caulk, Milford, Del.

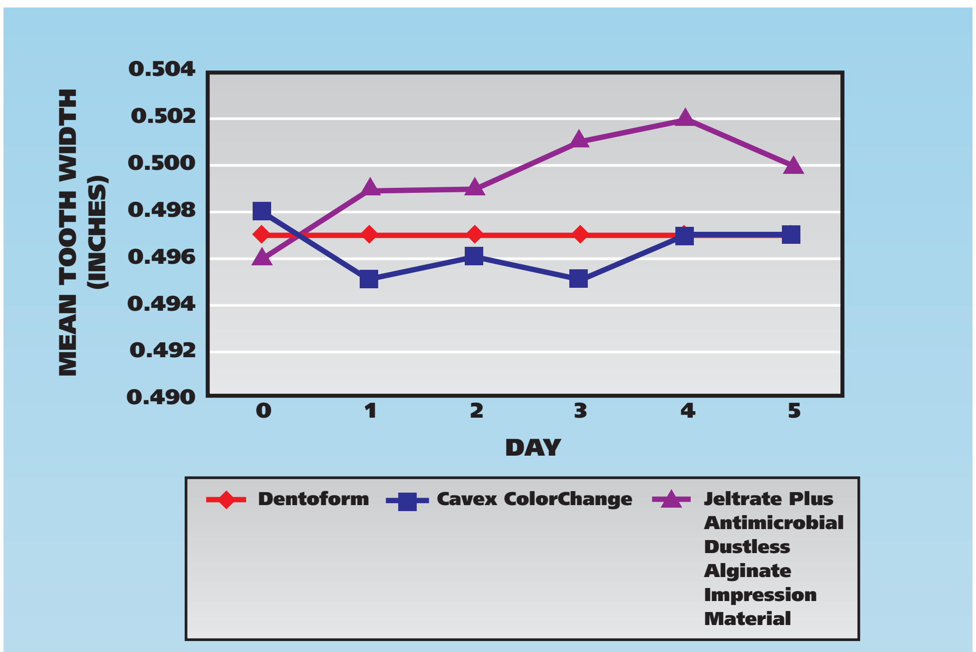

Figure 2. Mean tooth width. The Dentoform model is manufactured by Columbia Dentoform, Long Island City, N.Y. Cavex ColorChange impression material (extended-pour alginate) is manufactured by Cavex Holland BV, Haarlem, Netherlands. Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate) is manufactured by Dentsply Caulk, Milford, Del.

TABLE 2

Arch width characteristics.

DAY	MEAN ARCH WIDTH, INCHES*	95% CI†	*P* VALUE‡	PERCENTAGE OF DIMENSIONAL CHANGE	NO. OF SPECIMENS WITHIN 0.003 INCHES OF STANDARD MODEL MEASUREMENTS
Cavex ColorChange§					
0	2.348	2.345-2.350	.177	0.117	5
1	2.342	2.340-2.345	.003	−0.111	1
2	2.343	2.341-2.345	.014	−0.082	4
3	2.344	2.342-2.346	.084	−0.043	4
4	2.345	2.343-2.347	.454	0.009	5
5	2.346	2.344-2.348	.846	0.037	3
Jeltrate Plus Antimicrobial Dustless Alginate Impression Material¶					
0	2.346	2.343-2.348	.637	0.023	4
1	2.347	2.345-2.350	.306	0.100	5
2	2.347	2.345-2.350	.332	0.097	2
3	2.350	2.347-2.352	.006	0.193	2
4	2.348	2.345-2.350	.195	0.114	1
5	2.348	2.345-2.350	.214	0.111	3

* Standard error of the mean = 0.00113.
† CI: Confidence interval.
‡ Comparing estimated mean with actual arch width of 2.345 inches. A *P* value < .05 indicates that the mean is significantly different from the actual arch width.
§ Cavex ColorChange impression material (extended-pour alginate) is manufactured by Cavex Holland BV, Haarlem, Netherlands.
¶ Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate) is manufactured by Dentsply Caulk, Milford, Del.

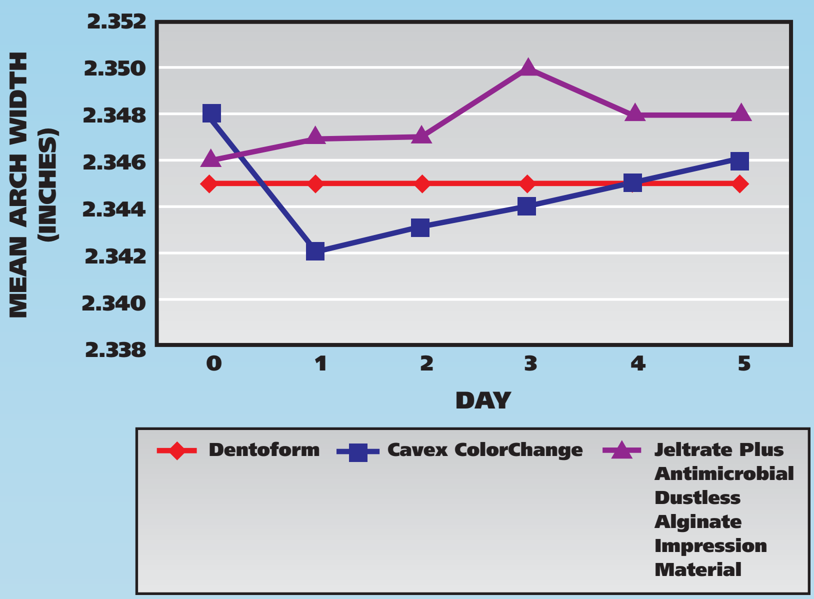

Figure 3. Mean arch width. The Dentoform model is manufactured by Columbia Dentoform, Long Island City, N.Y. Cavex ColorChange impression material (extended-pour alginate) is manufactured by Cavex Holland BV, Haarlem, Netherlands. Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate) is manufactured by Dentsply Caulk, Milford, Del.

ability to maintain accuracy across time. The processes that influence alginate dimensional stability are expansion due to water absorption (imbibition), shrinkage due to evaporation of water and syneresis (continued reaction of the sol). The first two processes depend primarily on storage conditions, and syneresis is affected by the proprietary constituents of the alginate.[13]

Free water. Water in an alginate gel is either free or bound. The free water is trapped among the filler particles and is susceptible to volumetric increases or decreases as a result of evaporation or imbibition. The amount of water lost through evaporation may be regained through imbibition.[10] One may speculate that movement of free water is explained easily, but nothing could be further from the truth. Nallamuthu and colleagues[14] explained that water loss depends on diffusion kinetics, decreases in entropy and changes in Gibbs free energy. Furthermore, complex osmotic pressures and gradient changes existing between the gel, sol and environment are specific for different alginate materials depending on proprietary ingredients.[15]

Bound water. Syneresis is the result of a rearrangement of cross-linked alginic polymer chains to a more stable configuration, resulting in exudation of the formerly bound water. This water movement may occur rapidly even in 100 percent humidity. Using nuclear magnetic resonance spectroscopy and moisture sorption isotherms, Fellows and Thomas[16] proposed that alginates with a higher ratio of calcium to sodium lose water more rapidly than do alginates with a lower ratio of calcium to sodium even though they exhibit greater dimensional stability. In addition, these authors[16] observed improved dimensional stability with alginates that contain higher ratios of filler to alginic polymer and lower-weight molecular polymer chains.

Chromatic alginates such as Cavex ColorChange contain additives that control the pH. The initial mix of chromatic alginates usually is alkaline, with a pH approximating 11 that decreases to near neutrality when set.[13] The influence of these additives on dimensional stability has not been examined, to our knowledge, but it may have a beneficial role.

Dimensional changes. The behavior of the two impression materials with regard to dimensional changes across five days is, therefore, multifactorial and material specific. These factors include syneresis, movement of free water via evaporation and imbibition, ratios of calcium to sodium and filler to polymer, molecular weight of alginic polymers and other proprietary constituents. Consequently, dimensional change as it relates to syneresis is controlled, to a large extent, by the manufacturer of the impression material.

From this discussion, we might expect that the dimensional stability of the two impression materials differs. With regard to the conventional alginate material, the greatest discrepancy from the standard model was 0.005 inches (125 micrometers), which occurred in tooth width when casts were generated on day 4 and in arch width when casts were generated on day 3. The greatest discrepancy demonstrated by the extended-pour alginate material was 0.003 inches (approximately 75 μm), which occurred in arch width when casts were generated immediately and on day 1.

It is apparent that casts produced from the extended-pour alginate are more accurate when they are not generated immediately, while casts produced from the conventional alginate are more accurate when generated before day 2. The results of a recent study by Sedda and colleagues[17] support the benefits of generating the casts produced from the conventional alginate sooner.

An initial increase in arch width occurred with

TABLE 3

Comparison of Cavex ColorChange* with Jeltrate Plus Antimicrobial Dustless† impression materials.

DAY	TOOTH WIDTH *P* VALUE‡	ARCH WIDTH *P* VALUE‡
0	.353	.477
1	.020	.003
2	.122	.011
3	.004	.001
4	.009	.129
5	.084	.283

* Cavex ColorChange impression material (extended-pour alginate) is manufactured by Cavex Holland BV, Haarlem, Netherlands.
† Jeltrate Plus Antimicrobial Dustless Alginate Impression Material (conventional alginate) is manufactured by Dentsply Caulk, Milford, Del.
‡ A P value < .05 indicates a statistically significant difference between the two products.

both impression materials (0.003 inches for the extended-pour alginate and 0.001 inches for the conventional alginate). A net contraction in the material usually follows the formation of the insoluble gel, and the contraction may continue even if the impression is immersed in a liquid.[10] In addition, both impression materials may have undergone shrinkage as a result of syneresis and water evaporation after being removed from the water bath. If the impression material is bonded firmly to the tray, shrinkage will result in the impression material's being pulled toward the tray and palatal areas, causing an increase in tooth and arch widths. During imbibition, the opposite phenomenon occurs, with the impression material's swelling resulting in smaller dimensions of the gypsum cast.

The conventional alginate material exhibited a statistically significant increase in tooth width on days 3 and 4 and in arch width on day 3. This was followed by a moderate decrease in dimensions (0.002 inches) by day 5. The operator had wrapped the impressions in damp paper towels, which may not have compensated for the combined effects of evaporation and syneresis.

After producing initially larger cast dimensions (day 0), the extended-pour alginate material experienced a significant decrease in tooth and arch widths on day 1, but returned to the standard dimensions of the model on day 5. Immediately after gel formation, a large volume of free water may have been held by the filler in the extended-pour alginate material, causing the impression to swell and resulting in smaller cast dimensions. From day 1 through day 5, evaporation of free water may have helped these impressions shrink, resulting in larger casts until they nearly reproduced the measurements of the standard model on day 5.

Clinical acceptability. For casts to be clinically acceptable, we considered a mean of 0.003 inches (75 μm) to be the greatest allowable deviation from the standard model's tooth and arch width measurements. In addition, we decided that three of the five specimens should meet this standard. Although clinicians do not use irreversible hydrocolloids for fixed prosthetic treatment, we selected 0.003 inches because investigators[18,19] conducting in vivo and in vitro studies determined that the range of marginal discrepancy that is clinically acceptable for cast and ceramic restorations is between 27 and 83 μm. Tables 1 and 2 show the number of specimens in each experimental group that met our standard of clinical acceptability. The extended-pour alginate material met our standard for all periods except day 1 for tooth and arch widths. The conventional alginate material produced fewer than three acceptable specimens on days 2, 3 and 4 with regard to arch and tooth widths.

For casts to be clinically acceptable, the authors considered a mean of 0.003 inches to be the greatest allowable deviation from the standard model's tooth and arch width measurements.

American Dental Association (ADA) specification no. 18 (dental alginate impression material)[20] does not stipulate the maximum allowable percentage of dimensional change for alginate impression materials. However, ADA specification no. 19 enumerates the maximum allowable dimensional change for elastomeric impression materials to be 0.40 percent for polysulfides and 0.60 percent for silicones.[21] Therefore, we compromised and chose 0.50 percent maximum allowable dimensional change to be the standard in this study. Casts produced from the extended-pour alginate impression material did not exceed this parameter at any period. The percentage of dimensional change ranged from –0.496 to 0.161 percent (Tables 1 and 2). However, casts produced from the conventional alginate impression material exceeded the parameter on day 3 (0.778 percent), day 4 (0.912 percent) and day 5 (0.671 percent) with regard to tooth width. These findings support the generation of casts from the conventional alginate impression material no later than day 2.

Our protocol involving the use of a model with convex embedded landmarks worked well and was more clinically applicable than use of the ADA specification no. 18 die with three ruled lines of 25-μm, 50-μm and 75-μm widths.[20] Our protocol included careful precautions to ensure a uniform material thickness by customizing palatal vaults of stock trays with impression compound and seating the trays in a reproducible manner. The largest bulk of impression material usually is in the palatal region. Excess material in this region may undergo more dimensional change than it does in other areas that contain a thinner amount of material.[9]

Using a dial-caliper micrometer, which is accurate to 0.001 inch (25 μm), and measuring the greatest distance between two convex surfaces three times was a reliable technique for measuring dimensional accuracy. Techniques involving the use of optical microscopes, which are capable of discerning as little as 1 μm and much more precise than dial calipers, are not representative of common clinical applications. Dimensional discrepancies as small as several micrometers are clinically insignificant because the crystalline structure of the gypsum products cannot reproduce such detail.[22]

The dimensional accuracy of casts produced from alginates also is influenced by factors other than syneresis, evaporation, imbibition and proprietary constituents controlled by the manufacturer. Random errors may arise from many sources when a clinician makes an impression and generates a gypsum cast. Such sources include incorrect ratios of gypsum powder to water, alginate unsupported by the tray, movement of the tray during gelation, alginate debonding from the tray, incorrect removal of the tray from the mouth and prolonged contact of the alginate with the gypsum product.[9] Dental gypsum products exhibit a net expansion during setting. Microstone has a maximum net expansion of 0.12 percent,[23] which may partly negate the effects of imbibition.

In addition, stresses occur in alginate impression materials during gelation when unequal pressures are applied to the tray. Within a short time after the clinician removes the tray from the mouth, these stresses are relaxed, resulting in a distorted impression.[9] Johnson and colleagues[24] also reported distortion of the mandible ranging from 100 to 500 μm during impression making. This distortion is larger than the greatest dimensional changes recorded for both impression materials in our study. Furthermore, fabrication of acrylic prostheses introduces additional and possibly significant random errors.

In this study, both impression materials, when stored properly, are dimensionally stable enough for fabrication of diagnostic casts, occlusal splints, acrylic appliances and possibly removable partial denture frameworks. The decades-old tenet that alginate impression materials must be poured immediately and never be immersed in a liquid, wrapped in a damp towel or stored before casting in gypsum no longer may be valid for every alginate impression material if stored adequately for limited times.

CONCLUSION

The dimensional accuracy of casts produced from the two alginate impression materials is time and material dependent. Under specified storage conditions, both impression materials used in this study produced casts that were statistically accurate compared with the Dentoform model at day 5. However, for best results, gypsum products for Jeltrate Plus Antimicrobial Dustless Alginate Impression Material should be poured no later than day 2 and those for Cavex ColorChange may be poured after day 2.

The extended-pour alginate material had the tendency to produce smaller casts and the conventional alginate material produced larger casts. The extended-pour alginate material did not exceed our standard of 0.50 percent dimensional change at any time. However, the conventional alginate exceeded it with regard to tooth width at days 3 (0.778 percent), 4 (0.912 percent) and 5 (0.671 percent). The extended-pour alginate met our standard of producing three of five casts within 0.003 inches of the standard model's dimensions at all periods except day 1. The conventional alginate met this standard when casts were generated immediately and on days 1 and 5. ■

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