Three-Dimensional Evaluation of Extended Pour Alginate Impression Materials Following Variable Storage Time Intervals and Conditions

Abstract

Purpose: The purpose of this study was to assess and compare the dimensional accuracy of the stone casts made of three extended pour alginate impressions materials (Cavex Colorchange, Kromopan, and Neocolloid) following storage under different storage conditions and pouring at different time intervals. Materials and Methods: A maxillary Frasaco (dentulous) model was selected as a standard model. Index holes of 1 mm depth and 1 mm diameter were made on the palatal cusp tips of right and left first premolars, mesiopalatal cusp tips of right and left third molars and in the midline of the palate, perpendicular to a line joining the index holes made on cusp tips of the first premolars as reference points for measurement. A single uniformly spaced custom tray was fabricated with heat-cure acrylic resin and used to make impressions for the entire study. A total of 210 impressions of the master model were made, seventy impressions were made from each of the alginate material brands and were subjected to three storage conditions (open air, uncontrolled humidity, and 100% controlled humidity) for three different storage time intervals (0, 1, 6 h). Since no storage was done in the immediate-pour group, it contained 10 specimens from each brand. Following the designated storage time interval, all impressions were poured in type IV gypsum. Measurements of stone casts were done in three dimensions, anteroposterior, lateral using Measuroscope and vertical by Dial Gauge. Data were organized in tables and statistical analyses were performed. Three-way ANOVAs were used to check if the material brands, storage time intervals, and conditions affect the measurements. Tukey HSD post hoc tests were used for the multiple comparisons if ANOVA is significant. One sample t-test was used to compare between the casts made of alginate brands and the master model. Significance level was set to α < 0.05 for all tests. Results: Results showed that the material brands, storage time intervals, and conditions do affect the measurements in all three dimensions (all P < 0.05). In addition, all two-way and three-way interactions were significant for all measurements except the interaction of storage time intervals and conditions for B–C (lateral) measurements, and interaction of material brands and storage time intervals for C–D (anteroposteriorly) measurements. When stone casts were compared to the master model, immediate pour, and storage for 1 h in 100% controlled humidity resulted in statistically insignificant changes among all three alginate impression brands. In addition, the specimens made of Cavex Colorchange and Kromopan following storage in uncontrolled humidity condition for 1 h showed statistical insignificance when compared to the master model. Conclusion: Within the limitations of this study, it can be extrapolated that, although this class of alginate impression materials was manufactured for extended pour purposes, clinicians should avoid storage of the studied brands for 6 h. Whenever 1 h to pour is necessary, 100% controlled humidity is the ideal and standardized environment for all three alginate brands. Perhaps, Cavex Colorchange, and Kromopan can be safely stored in uncontrolled humidity condition while maintaining their optimal dimensional accuracy.

Keywords: Alginate impressions, dimensional accuracy, extended pour alginate, irreversible hydrocolloids

Introduction

Impression making and pouring are critical steps in the process of producing successful dental appliances, restorations, and prostheses. Impression materials should reproduce the hard and soft tissues accurately to obtain biologically, mechanically, functionally, and esthetically acceptable treatment outcomes.[1] Accurate diagnostic casts are essential to perform multitude of functions throughout the diagnosis, treatment planning, and preparatory phase of prosthodontic care.[2,3] Although there are several impression materials and procedures to choose from, research continues to compare the available impression materials for various procedures.

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available for accurate impression making, irreversible hydrocolloids are one of the several impression materials that are commonly used in the dental office to produce stone casts. Ease of use, low cost integrated with good clinical and physical properties make alginate a popular choice among variable dental practices.

Nevertheless, low dimensional stability is considered as the most concerning shortcoming of irreversible hydrocolloids on clinical use. Dimensional stability can be defined as the ability of a material to maintain accuracy across time. Water absorption (imbibition) and water release (syneresis) that occurs over time resulted in the production of inaccurate casts, and it was generally recommended that irreversible hydrocolloid impressions be poured immediately or within a window of 10–12 min after removal from the mouth without wrapping in a damp paper towel. Cohen and coworkers studied the dimensional stability of three conventional brands of irreversible hydrocolloid impression materials under five different storage conditions at different time intervals of 10 min, 30 min, 1 h, and 24 h before pouring. They concluded that immediate pouring made the most accurate cast. Moreover, three in vitro studies were conducted to compare between the conventional and extended pour alginate and reported that conventional alginate were dimensionally stable when immediately poured while extended pour alginate maintained dimensional stability when stored adequately up to 5 days.

Numerous studies have evaluated the dimensional accuracy of conventional alginate impressions and reported that it is possible to store them in a humid environment for up to one, two, and even four hours, while others suggested to store them in damp paper towels, rather than immediate pouring. Recently, a new generation of alginate impression materials, namely, extended-pour, have been introduced to overcome the shortcomings that were noted in conventional alginate products. This generation of alginate materials was found capable of maintaining their dimensional stability and accuracy with delayed pouring times of up to 5 days, given that impressions are wrapped in damp towels or sealed in plastic bags.

Although the current dental literature reveals numerous studies that compare dimensional accuracy between conventional and extended pour alginate, these studies have utilized either one-dimensional linear reproduction models or two-dimensional measurement technique on standard acrylic models and mostly used measurement tools with limited accuracy that may question their validity for clinical applications. In fact, the dimensional changes in alginate under the effect of storage time and media are much more complex and require rather an advanced evaluation approach in three dimensions to be able to apply the outcomes in a real-world clinical setting. Therefore, the present study was designed and aimed to assess three-dimensional changes following variable storage time intervals and conditions of three extended pour alginate impression materials. The null hypothesis of this study stated that the brand of alginate, storage time intervals, and conditions do not affect the dimensional accuracy of extended pour alginate impression materials and therefore their generated stone casts.

Materials and Methods
Specimen preparation and measurement

Three commercially available extended-pour alginate materials: Cavex Colorchange (Cavex Holland, RW Haarlem, Netherlands), Kromopan (Lascod Spa, Florence, Italy), and Neocollod (Zhermack, Badia Polesine, Italy) were included in this study. Although various methodologies were followed to study physical properties of alginate impression materials, the method followed in this study was indirect one. Hence, measurements were done on the casts obtained by pouring alginate impressions rather than measuring the impressions themselves. A standard maxillary dentulous acrylic model (Frasco GmbH, Tettinang, Germany) was selected as master model [Figure 1A]. Index holes of 1 mm depth and diameter were made using a round acrylic bur (Brasseler, Savannah, GA). These holes were made on the palatal cusp tips of the right and left first premolars, mesiopalatal cusp tips of the right and left third molars and on the midline of the palate perpendicular to a line joining the index holes that were made on the first premolars. The holes were used as reference points for standardized and repeatable measurement.

In a step to standardize impression making throughout the study, a single uniformly spaced custom tray using heat-cure acrylic resin for strength and accuracy was fabricated. The custom tray was checked on the master model for uniform space adequacy, fit, and extension. A straight fissure bur of 2 mm diameter was used to make holes 3 mm apart throughout the custom tray to provide adequate mechanical retention for the alginate impression material and avoid the need for tray adhesive. The master model was mounted on phantom head for clinical simulation and convenience. Manufacturer’s instructions with respect to powder/water

Figure 1: (A) the master model and (B) schematic representation of the planned measurement dimensions in anterior-posterior (a-b and c-d), lateral (b-c) and vertical (e-f) directions
ratio, working, and setting times were strictly followed for each brand. Manual mixing was done using a clean rubber bowl and plaster spatula for all alginate brands. The custom tray was loaded and oriented on the master model accordingly. Following the complete set, the impressions were removed in a snap movement in a direction parallel to the long axis of teeth.

A total of 210 alginate impressions of master model were made, seventy impressions were made from each alginate brand and were subjected to three different storage time intervals (0, 1, 6 h) and three storage conditions (open air, uncontrolled humidity where each impression was wrapped in damp paper towel only, and 100% controlled humidity where each impression was wrapped in damp paper towels and stored in sealed plastic bags that were kept in an airtight plastic container that was lined with a water saturated paper towel).[25-27] Since no storage was done for immediate-pour group, it contained 10 specimens from each brand. Following the designated storage time intervals, all impressions were poured in type IV gypsum product under vibration and were allowed to set following the manufacturer’s recommendation before cast separation from the alginate impressions. Silicone base former (Pearson Dental, Sylmar, CA) was used to ensure consistency of base thickness among all study specimens. All casts were checked for any defects and allowed to bench set for 24 h before measurement. The casts were coded in a single-blinded method. Measurements were done in three dimensions: Anteroposterior (AP) (A–B, C–D), lateral (B–C), and vertical (E–F) dimensions as shown in Figure 1B. For AP and lateral measurements, a measurement microscope (Measuroscope, Nikon, Japan) with accuracy of 0.001 mm was used. Specimens were placed in a predetermined static position on the microscope’s horizontal platform. Calibration was set on zero at one reference point, for the desired measurement dimension, and scanned up to the other reference point. The distance between the two reference points was recorded in AP and lateral dimensions. For vertical measurement, a dial gauge (Dial Indicator, Mitutoyo, Japan) with an accuracy of 0.005 mm was used. Specimens were placed in a predetermined static position on its horizontal platform. A straight metal plate was placed in contact with the palatal cusp tips of the right and left first premolars. This plate was used as a reference on vertical measurements. First, the distance from the zero position of the dial gauge to the lower edge of the plate was recorded. The tip of the gauge was lowered further until it touched the index hole located on the palate between the right and left first premolars. The dial reading was again recorded. The vertical measurement (E–F) was then calculated by subtracting the zero-to-plate and overall dials readings. Measurements were done by a single-blinded expert investigator. Each measurement, in all dimensions, were done thrice and averaged.

Statistical analysis

The recorded data were entered into a Microsoft Excel Spreadsheet (Microsoft Inc., Redmond, WA). Data were organized in tables, and statistical analyses were performed to compare the stone casts between the brands and to the master model. Statistical analysis software (IBM SPSS Inc., Statistics v. 24, Chicago, Illinois, United States) was used for analysis. Three-way ANOVAs were used to investigate if the material brands, storage time intervals, and conditions affect the measurements in A–B, B–C, C–D, and E–F dimensions. Tukey HSD post hoc tests were used for multiple comparisons only if ANOVA revealed statistical significance. One sample t-test was used to compare between the casts made of alginate brands and the master model. The significance level was set to α < 0.05 for all tests.

Results

The results of the statistical analysis showed that the material brands, storage time intervals, and storage conditions do affect the measurements in all dimensions (all P < 0.05). In addition, all two-way and three-way factor interactions were significant for all measurement dimensions except the interaction of storage time intervals and conditions in lateral (B–C) dimension and the interaction of material brands and storage time intervals in AP (C–D) dimension.

Table 1 shows the descriptive statistics and the three-way ANOVA results for the AP (A–B) measurement dimension. Cavex Colorchange had significantly (P < 0.001) smaller mean measurement than Kromopan and Neocolloid. No statistically significant differences were detected between the immediate and 1 h storage time intervals; however, both had significantly (P < 0.001) smaller mean measurement than 6 h storage time interval. Evaluation of the storage conditions revealed that immediate pour (nonstorage) condition had significantly smaller mean measurement than the open air and uncontrolled humidity.

Table 2 shows the descriptive statistics and the three-way ANOVA results for the lateral (B–C) measurement dimension. Kromopan had significantly (P < 0.001) higher mean measurement than Cavex Colorchange and Neocolloid. Immediate pour and 1 h storage time were not significantly different in measurement; however, both had significantly (P < 0.001) smaller mean measurement than the 6 h storage time interval. Evaluation of the storage conditions revealed that that immediate pour (nonstorage) condition had significantly smaller mean measurement than all other storage conditions.

Table 3 shows the descriptive statistics and the three-way ANOVA results for the AP (C–D) measurement dimension. Cavex Colorchange had significantly (P < 0.001) larger mean measurement than Kromopan and Neocolloid. Immediate pour had significantly (P < 0.001) smaller mean measurement than 1 and 6 h storage time intervals, while
Table 1: Descriptive statistics and three-way ANOVA results for the anteroposterior measurement dimension (A–B)

| Factors                  | Subfactors                | n  | Mean    | SD   | P           | Tukey HSD post hoc test** |
|--------------------------|---------------------------|----|---------|------|-------------|---------------------------|
| Material                 | Cavex Colorchange         | 70 | 30.51   | 0.36 | <0.001*     | A                         |
|                          | Kromopan                  | 70 | 30.64   | 0.25 |             | B                         |
|                          | Neocolloid                | 70 | 30.64   | 0.27 |             | B                         |
| Storage time             | Immediate                 | 30 | 30.46   | 0.32 | <0.001*     | A                         |
|                          | 1 h                       | 90 | 30.53   | 0.29 |             | A                         |
|                          | 6 h                       | 90 | 30.71   | 0.28 |             | B                         |
| Storage condition        | None                      | 30 | 30.46   | 0.32 | <0.001*     | A                         |
|                          | Open air                  | 60 | 30.73   | 0.28 |             | C                         |
|                          | Uncontrolled humidity     | 60 | 30.61   | 0.29 |             | B                         |
|                          | Controlled humidity       | 60 | 30.52   | 0.29 |             | A                         |

Material × storage time   | 0.044*                    |
Material × storage condition | <0.001*                  |
Storage time × storage condition | 0.011*               |
Material × storage time × storage condition | 0.010*              |

*The mean difference is significant at the 0.05 level, **Different letters mean significantly different (A < B < C). HSD=Honest significant difference, SD=Standard deviation

1 h storage time interval had significantly (P < 0.001) smaller mean measurement than the 6 h storage time interval. Evaluation of storage conditions revealed that immediate pour (nonstorage) condition had significantly smaller mean measurement than all other storage conditions.

Table 4 shows the descriptive statistics and the three-way ANOVA results for the vertical (E–F) measurement dimension. Neocolloid had significantly larger mean measurement than Cavex Colorchange and Kromopan. The immediate storage time interval had significantly (P < 0.001) smaller mean measurement than 1 h and 6 h storage time intervals, while 1 h storage time interval had significantly (P < 0.001) smaller mean measurement than 6 h storage time interval. Evaluation of storage conditions revealed that immediate pour (nonstorage) condition had significantly (P < 0.001) smallest measurement among all the storage conditions followed by the uncontrolled humidity and controlled humidity storage conditions.

Table 5 shows statistical comparisons between the generated stone casts and the master model in all measurement dimensions with variable combinations of material brands, storage time intervals, and conditions. No statistical significance was detected in casts made of Cavex Colorchange when impressions poured immediately, however when stored for 1 h at room temperature in

Table 2: Descriptive statistics and three-way ANOVA results for the lateral measurement dimension (B–C)

| Factors                  | Subfactors                | n  | Mean    | SD   | P           | Tukey HSD post hoc test** |
|--------------------------|---------------------------|----|---------|------|-------------|---------------------------|
| Material                 | Cavex Colorchange         | 70 | 32.24   | 0.25 | <0.001*     | A                         |
|                          | Kromopan                  | 70 | 32.38   | 0.20 |             | B                         |
|                          | Neocolloid                | 70 | 32.26   | 0.25 |             | A                         |
| Storage time             | Immediate                 | 30 | 32.15   | 0.16 | <0.001*     | A                         |
|                          | 1 h                       | 90 | 32.22   | 0.26 |             | A                         |
|                          | 6 h                       | 90 | 32.41   | 0.19 |             | B                         |
| Storage condition        | None                      | 30 | 32.15   | 0.16 | 0.012*      | A                         |
|                          | Open air                  | 60 | 32.37   | 0.23 |             | C                         |
|                          | Uncontrolled humidity     | 60 | 32.31   | 0.26 |             | B                         |
|                          | Controlled humidity       | 60 | 32.20   | 0.24 |             | B                         |

Material × storage time   | 0.044*                    |
Material × storage condition | 0.007*                  |
Storage time × storage condition | 0.094              |
Material × storage time × storage condition | <0.001*              |

*The mean difference is significant at the 0.05 level, **Different letters mean significantly different. A < B < C. HSD=Honest significant difference, SD=Standard deviation
open air, statistically significant changes were seen in AP and vertical dimensions. Furthermore, storage for 6 h resulted in statistically significant changes in all three dimensions matching the results seen in Neocolloid- and Kromopan-based specimens. Storage in uncontrolled humidity condition for 1 h showed statistically insignificant changes in all three dimensions, but when storage was done for 6 h, statistically significant changes became evident in all three dimensions that was similar to the storage for 6 h at room temperature in open air. The specimens that were stored in a 100% controlled humidity condition for 1 h showed statistically insignificant changes in all dimensions, while storage in the same condition for 6 h resulted in statistically significant changes in lateral and vertical dimensions with no significant effect on AP dimension.

Moreover, when Kromopan specimens were poured immediately, statistically insignificant changes were noted in all three dimensions; however, 1 h storage at room temperature in open air resulted in statistically significant changes in lateral and vertical dimensions, while storage for 6 h showed statistically significant changes in all three dimensions that was similar to the results seen in Cavex Colorchange and Neocolloid. The storage of Kromopan specimens in uncontrolled humidity condition for 1 h showed statistically insignificant changes in all three dimensions; however, 6 h storage resulted in significant changes in all three dimensions that was similar to storage for 6 h at room temperature in open air. Storage in 100% controlled humidity condition for 1 h revealed statistically insignificant changes in all three dimensions similar to uncontrolled humidity storage for 1 h. Nonetheless, storage

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### Table 3: Descriptive statistics and three-way ANOVA results for the anteroposterior measurement dimension (C–D)

| Factors             | Sub-factors          | n  | Mean | SD  | P       | Tukey HSD post hoc test** |
|---------------------|----------------------|----|------|-----|---------|--------------------------|
| Material            | Cavex Colorchange    | 70 | 30.56| 0.39| 0.001* | B                        |
|                     | Kromopan             | 70 | 30.42| 0.27| A       |                          |
|                     | Neocolloid           | 70 | 30.38| 0.31| A       |                          |
| Storage time        | Immediate            | 30 | 30.19| 0.22| <0.001*| A                        |
|                     | 1 h                  | 90 | 30.39| 0.32| A       |                          |
|                     | 6 h                  | 90 | 30.61| 0.31| B       |                          |
| Storage condition   | None                 | 30 | 30.19| 0.22| 0.004* | A                        |
|                     | Open air             | 60 | 30.59| 0.31| B       |                          |
|                     | Uncontrolled humidity| 60 | 30.47| 0.29| C       |                          |
|                     | Controlled humidity  | 60 | 30.44| 0.37| B       |                          |
| Material × storage time   |                     |     |      |      | 0.310  |                          |
| Material × storage condition |                 |     |      |      | <0.001*|                          |
| Storage time × storage condition |             |     |      |      | 0.002* |                          |
| Material × storage time × storage condition |         |     |      |      | 0.018* |                          |

*The mean difference is significant at the 0.05 level, **Different letters indicate significant difference (A < B < C). HSD=Honest significant difference, SD=Standard deviation

### Table 4: Descriptive statistics and three-way ANOVA results for the vertical measurement dimension (E–F)

| Factors             | Sub-factors          | n  | Mean | SD  | P       | Tukey HSD post hoc test** |
|---------------------|----------------------|----|------|-----|---------|--------------------------|
| Material            | Cavex Colorchange    | 70 | 11.20| 0.17| 0.039* | A                        |
|                     | Kromopan             | 70 | 11.20| 0.18| A       |                          |
|                     | Neocolloid           | 70 | 11.26| 0.20| B       |                          |
| Storage time        | Immediate            | 30 | 11.14| 0.11| <0.001*| A                        |
|                     | 1 h                  | 90 | 11.26| 0.15| B       |                          |
|                     | 6 h                  | 90 | 11.33| 0.20| C       |                          |
| Storage condition   | None                 | 30 | 11.14| 0.11| <0.001*| A                        |
|                     | Open air             | 60 | 11.33| 0.24| C       |                          |
|                     | Uncontrolled humidity| 60 | 11.23| 0.16| B       |                          |
|                     | Controlled humidity  | 60 | 11.23| 0.12| B       |                          |
| Material × storage time   |                     |     |      |      | 0.013* |                          |
| Material × storage condition |                 |     |      |      | <0.001*|                          |
| Storage time × storage condition |             |     |      |      | <0.001*|                          |
| Material × storage time × storage condition |         |     |      |      | <0.001*|                          |

*The mean difference is significant at the 0.05 level, **Different letters indicate significant difference (A < B < C). HSD=Honest significant difference, SD=Standard deviation
Table 5: Comparison between the master model and stone casts made of the alginate impressions relative to the storage time intervals (0=no storage, 1=1 h, 6=6 h), conditions (0=no storage, 1=open air, 2=uncontrolled humidity, 3=controlled humidity) and measurement dimensions in anteroposterior (A–B and C–D), lateral (B–C) and vertical (E–F) dimensions

| Material        | Storage time | Storage condition | A–B     | B–C     | C–D     | E–F     | P value of one sample t-test |
|-----------------|--------------|-------------------|---------|---------|---------|---------|-----------------------------|
| Cavex Colorchange | 0            | 0                 | 0.121   | 0.621   | 0.381   | 0.464   |                             |
|                 | 1            | 1                 | 0.042*  | 0.938   | 0.001*  | 0.001*  |                             |
|                 | 6            | 1                 | <0.0001*| <0.001* | <0.001* | <0.001* |                             |
|                 | 1            | 2                 | 0.518   | 0.228   | 0.311   | 0.209   |                             |
|                 | 6            | 2                 | 0.001*  | <0.001* | <0.001* | 0.001*  |                             |
|                 | 1            | 3                 | 0.154   | 0.106   | 0.079   | 0.162   |                             |
|                 | 6            | 3                 | 0.349   | <0.001* | 0.059   | 0.001*  |                             |
| Kromopan        | 0            | 0                 | 0.313   | 0.068   | 0.311   | 0.074   |                             |
|                 | 1            | 1                 | 0.388   | <0.001* | 0.072   | 0.041*  |                             |
|                 | 6            | 1                 | <0.001* | 0.007*  | <0.001* | 0.011*  |                             |
|                 | 1            | 2                 | 0.652   | 0.081   | 0.488   | 0.192   |                             |
|                 | 6            | 2                 | 0.033*  | <0.001* | 0.005*  | <0.001* |                             |
|                 | 1            | 3                 | 0.521   | 0.084   | 0.547   | 0.387   |                             |
| Neocolloid      | 0            | 0                 | 0.082   | 0.609   | 0.098   | 0.121   |                             |
|                 | 1            | 1                 | 0.462   | 0.048*  | 0.082   | 0.004*  |                             |
|                 | 6            | 1                 | 0.007*  | <0.001* | 0.003*  | 0.012*  |                             |
|                 | 1            | 2                 | <0.001* | 0.021*  | <0.001* | 0.003*  |                             |
|                 | 6            | 2                 | 0.043*  | <0.001* | 0.001*  | 0.014*  |                             |
|                 | 1            | 3                 | 0.71    | 0.64    | 0.934   | 0.078   |                             |
|                 | 6            | 3                 | 0.012*  | 0.095   | 0.038*  | 0.039*  |                             |

*Statistical significant difference

for 6 h showed statistically significant changes in vertical and lateral dimensions, that is, similar to Cavex Colorchange storage for 6 h in controlled humidity condition.

Statistically insignificant changes were seen in Neocolloid specimens when poured immediately, although storage for 1 h at room temperature in open air resulted in statistically significant changes in lateral and vertical dimensions. Nevertheless, storage for 6 h at room temperature in open air showed statistically significant changes in all three dimensions similar to Cavex Colorchange and Kromopan specimens at the same storage time and condition. Storage in uncontrolled humidity condition for 1 h as well as storage for 6 h showed statistically significant changes in all three dimensions similar to Cavex Colorchange and Kromopan specimens when poured immediately, although storage for 6 h in uncontrolled humidity condition. Storage in 100% controlled humidity condition for 1 h showed statistically insignificant changes in all three dimensions similar to Cavex Colorchange and Kromopan storage in controlled humidity for 1 h, however when stored for 6 h, statistically significant changes were evident in AP and vertical dimensions.

**Discussion**

Alginate impression materials consist of a powder that when mixed with water forms a fast-setting gel. The reactive constituents of alginate 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 to result in gel formation. In addition, fillers and smaller amounts of other proprietary ingredients are added to control consistency, setting time, elasticity, strength, and dimensional stability. Fellows and Thomas proposed that alginites with a higher ratio of calcium to sodium lose water more rapidly than do alginites with a lower ratio, although they exhibit greater dimensional stability. In addition, they observed an improved dimensional stability with alginites that contain higher ratios of fillers to alginic polymer and lower-weight molecular polymer chains. Chromatic alginites, such as Cavex Colorchange, contain additives that control their pH level on reaction. The initial mix of chromatic alginites is usually alkaline, with a pH approximating 11, which decreases to near neutrality when impression material is set.

The behavior of alginate materials in regard to dimensional changes over storage time is multifactorial and material specific. These factors include syneresis and imbibition, ratios of calcium to sodium and filler to polymer, molecular weight of alginic polymers and other proprietary constituents. These factors primarily depend on storage conditions, while syneresis is mainly affected by the proprietary constituents of the alginate. In the contrary to the conventional alginate impression materials, the authors expected the accuracy and dimensional stability
of extended-pour alginate impression materials to differ significantly. The impression specimens in this study were stored at room temperature either in open air, uncontrolled humidity, or 100% controlled humidity that was proposed by multiple isolated studies in an effort to find the ideal storage condition for alginate impressions. Some clinical instances necessitate delayed impression pour. Relative to the other storage media, the 100% controlled humidity is comparable with respect to time and material requirements since they are readily available in the vicinity of the dental office. This simple way of achieving 100% controlled humidity and its effectiveness is being studied in this experiment.

The storage time intervals used in this study were chosen to simulate the routine handling of alginate impression materials in daily clinical practice. Immediate impression pour is possible when clinicians have time availability between consecutive appointments or in case laboratory support is available within the vicinity of the clinical operatory. One hour storage was set as an experimental time interval due to the fact that many practitioners dismiss their patients within an hour following an initial short dental appointment, while 6 h storage was chosen to represent busy clinical practices where practitioners find time to pour the impressions at the end of the practice day due to closely packed appointments or in case a laboratory support is not accessible.

Wandrekar et al.\textsuperscript{[30]} stated that several compositional elements such as titanium, fluorine, and zinc to the composition were added to alginate impression materials in an attempt to improve their physical properties and compatibility with gypsum products on pouring. Nevertheless, in our study, an indirect evaluation method was undertaken to measure the resultant stone casts rather than alginate impressions themselves, due to the fact that pouring of irreversible hydrocolloids using gypsum materials is a standard clinical procedure. Dental gypsum products exhibit a net expansion during setting. All impressions were poured in type IV gypsum that has a low setting expansion rate of 0.08% as reported by the manufacturer, utilizing a manual mixing method under vibration to produce accurate casts.

Current studies have evaluated the accuracy and dimensional stability of alginate impression materials within two dimensions only, namely, AP and lateral.\textsuperscript{[2,3,11,13]} On the contrary, our study was designed to achieve three-dimensional evaluations with the addition of vertical measurement. The vertical measurement was done at the middle of the palate as Rudd et al.\textsuperscript{[9]} reported that excess material in palatal region may undergo more dimensional changes than it does in other areas that contain a thinner amount of material.\textsuperscript{[9]} Several techniques have been proposed for evaluation of the dimensional accuracy of stone casts to include microscopes,\textsuperscript{[31]} micrometers,\textsuperscript{[32]} dial gauges,\textsuperscript{[33]} calipers,\textsuperscript{[34]} and digital modeling;\textsuperscript{[23]} however, there is no common agreement as to which measurement tool is more acceptable than others. In the present study, a measuroscope with accuracy of 0.001 mm was used for measurement of AP (A–B, C–D), lateral (B–C) dimensions, while dial gauge with accuracy of 0.005 mm was used for evaluation of dimensional changes in vertical dimensions (E–F). Due to methodological differences, it is difficult to compare our findings with those of previous studies.

The accuracy and dimensional stability of alginate impressions and stone casts are multifactorial as they can be affected by chemical composition, clinical and laboratory manipulation, and condition of the storage environment. Many random errors may arise when a clinician makes an alginate impression and generates a stone cast. These errors may occur as a result of incorrect powder to water ratios, improper alginate support by the tray, movement of the tray during gelation, alginate debonding from the tray, incorrect removal of the tray from the mouth, type of trays used, the gypsum materials used to pour casts, disinfection material and procedure used, and time of contact between the alginate and gypsum materials before cast separation.\textsuperscript{[35]} Extended pour alginate impression materials have been recently introduced for clinical use. However, a careful review of literature shows scarcity of the published data on these materials in regard to their accuracy and dimensionally stability following variable storage time intervals and conditions before pouring stone casts. Therefore, this study was aimed to address this concern and evaluate these materials in clinically simulated scenarios.

Furthermore, the majority of the available studies\textsuperscript{[36-38]} had followed specification No. 18 that was issued by the American Dental Association (ADA), which was intentionally designed to replicate a clinical scenario,\textsuperscript{[19]} utilizing a cylindrical metal block to perform material evaluation in two horizontal coordinates separated by distances within 5 mm. However, some studies have recognized that this standard may not be sufficient to account for changes over three-dimensional coordinates\textsuperscript{[23]} or larger surface areas. The use of a definitive model in an arch-form configuration with unprepared teeth has been suggested as the best method for simulating the oral environment, as well as the stress involved in clinical dental casting.\textsuperscript{[40]} Impression material must be capable of flowing readily into undercut areas in the mouth, setting in that position, and rebound to its original shape after the set impression has been removed from the mouth.\textsuperscript{[9]} in a process referred to as elastic recovery. For these reasons, our study utilized a full-arch master model with undercuts and unprepared teeth. Our protocol included careful precautions to ensure a uniform material thickness as water-based impression materials have been found to provide maximum accuracy with a cross-sectional...
thickness of 4–6 mm. This uniform thickness was achieved by uniformly spaced custom tray with four stops, two on either side of arch in canine and molar region that oriented the tray in a reproducible position during impression making. Hand versus mechanical mixing has not been reported to result in any major differences in the physical properties of irreversible hydrocolloids. The alginate materials used in this study were hand-mixed by a single investigator.

The standardized impression technique developed for this study may be helpful in obtaining comparable results among different impression materials. It has been reported that under specific conditions, irreversible hydrocolloids designed for fixed prosthodontic restorations could produce accurate results similar to the ones obtained from reversible hydrocolloids, condensation, and addition silicones. This study would help clinicians to select a material among the three extended-pour alginates that is accurate in all three dimensions following storage in specific conditions for specific time intervals to be used for fabrication of fixed restorations, removable partial denture frameworks, and other routine procedures.

Coleman et al. observed no significant dimensional changes in conventional alginate impression materials whether poured immediately, stored for 30 min on countertop (open air), or stored for 1 h in a wet paper towel. The findings of this study are in agreement with the aforementioned study results when impressions made of all three extended-pour alginate materials were poured immediately, but when all three studied alginate impression specimens were stored for 1 h at room temperature in open air, stone casts showed statistically significant changes in at least two of the three dimensions. In addition, storage for 6 h showed statistically significant changes in all three dimensions indicating the need of a storage conditions that could compensate for syneresis and imbibition to maintain dimensional accuracy.

Morrant and Elphicke proposed that storage of conventional alginate impressions over a period of 1 h in a damp towel may be satisfactory but seems an unreliable method. This study findings are in agreement with their study for Cavex Colorchange and Kromopan materials when stored for 1 h in uncontrolled humidity as the stone casts made were accurate in all three dimensions; however, Neocollod showed statistically significant changes in all three dimensions. The authors stated that storage over a period of 1 h in a 100% humidity condition is much more reliable and standardized environment. Our findings are consistent with their proposed storage methodology as the stone casts made of all three tested alginate impression materials showed accuracy in all three dimensions when stored in 100% controlled humidity condition for 1 h.

Habu et al. suggested that storing alginate impressions at a 100% relative humidity environment for a long time is as risky for maintaining their accuracy as being left in open air. Our findings in regard to the accuracy of stone casts among the three selected alginate impression materials following storage for 6 h in 100% controlled humidity were consistent with their finding as they showed statistically significant dimensional changes in at least two of the three measured dimensions. Moreover, when the specimens of all alginate impression brands were stored for 6 h at room temperature and each storage condition, showed statistically significant changes in at least two of the three measured dimensions. Although several studies have supported maintenance of dimensional accuracy among extended, pour alginate materials following storage up to 5 days, our study findings suggest that clinicians should avoid storage of these alginate impression materials for 6 h in any of the storage conditions.

Significant changes in these dimensions may have discernible effects on the stone casts and therefore on the accuracy of diagnosis, occlusal devices, and interim prostheses that are made of them. While changes in AP dimensions cause occlusal errors in protrusive movement and shortening of AP arch dimensions, lateral dimensional changes may have significant effects on the working and nonworking side contacts and therefore occlusal interferences in lateral eccentric jaw movements. In addition, significant dimensional changes in lateral and vertical directions may affect the fit of fabricated devices and prostheses as lateral changes may contribute to narrower palate while vertical changes may result in deep palatal vault.

The ADA specification No. 18, for dental alginate impression materials, does not stipulate the maximum allowable percentage of dimensional change for alginate impression materials, while ADA specification No. 19 specified the maximum allowable dimensional change for elastomer impression materials to be 0.40% for polysulfide and 0.60% for silicones. Few researchers have adopted these cutoff values and proposed 0.50%, an average of the two cutoff values that were identified in ADA Specification No. 19, as the maximum allowable dimensional change for alginate impression materials. However, the limit values indicated in ADA Specification No. 19 cannot be applied to determine the limit value for alginates since these materials have numerous differences in chemical composition, reaction, physical properties, and behavior. In this study, direct comparisons were made between the master model and stone casts made of three extended pour alginate impression materials to identify the material that could replicate the dimensions of the master model accurately. It is recommended to set a limit value to specify the maximum allowable dimensional changes for alginate impressions to be used as a benchmark to study the dimensional changes among the available brands of alginate impression materials. Nonetheless, the results of this study recommend storage of all three selected alginate impressions in 100%
controlled humidity for 1 h to satisfy the outstanding clinical needs; however, this may not be applicable to all alginate impression materials. For storage of 1 h to pour, 100% controlled humidity is the ideal storage method for all the three materials. However, Cavex Colorchange and Kromopan can be safely stored in uncontrolled humidity condition for a period of 1 h while maintaining their dimensional accuracy. Storage of the studied alginate impression brands at room temperature in open air for 1 h or more should be avoided.

Storage of Cavex Colorchange and Kromopan for 1 h in uncontrolled humidity condition and any of the studied materials for 1 h in 100% controlled humidity condition did not significantly affect the dimensional accuracy of the resultant stone casts, that might provide clinicians a sufficient time to finish necessary chairside procedures, and therefore leading to improved operator efficiency and clinical time management.

The intended clinical applications of irreversible hydrocolloid impressions should be considered to determine the degree of accuracy that is anticipated in this class of dental impression materials. The use of irreversible hydrocolloids for fabrication of removable partial denture frameworks, occlusal splints, orthodontic appliances and surgical guides require a greater degree of accuracy. Erickson et al.[48] in a longitudinal clinical study, estimated the survival rate of fixed restorations/ prostheses made of alginate impressions and found comparable rates to other impression materials that were reported in other clinical studies, after 5 years (99%), 10 years (93%–96%), 15 years (74%–96%), and 20 years (61%–63%). To achieve this goal, our study findings suggest that immediate pour could become a necessity if the storage time, storage conditions, and temperatures are unknown. In addition, the type of irreversible hydrocolloid impression material used has an important role since irreversible hydrocolloids are not equal in their behavior under comparable storage time intervals and conditions. Therefore, clinicians should select the alginate impression brand carefully and according to the intended clinical application.

The present study has certain limitations. Since this was an in vitro study, an exact simulation of the oral conditions in terms of mouth temperature, existence of blood, saliva, soft tissues, and undercuts could not be achieved to evaluate the studied impressions in an idealized model. Moreover, due to the difficulty in applying adhesive material in a uniform thickness, no adhesive material was applied on the custom trays; however, mechanical means of impression retention was sufficient to achieve our study purposes. The study has been standardized and single experienced investigator performed all required procedures to prevent gross manipulative variations, while the measurements were done by the other investigator in a single-blinded fashion. Further studies are required to evaluate these materials under simulated oral conditions.

**Conclusion**

Within the limitations of this study, the following conclusions can be drawn:

1. All studied brands of alginate impressions materials showed insignificant dimensional changes when they were poured immediately, making it the best choice for pouring alginate impressions
2. Clinical conditions that necessitate storage of 1 h to pour stone casts, the storage condition of 100% controlled humidity, is the standard environment for all studied alginate brands. In addition, Cavex Colorchange and Kromopan can be safely stored for 1 h in uncontrolled humidity condition while maintaining their optimal dimensional accuracy
3. Although these alginate impression brands were manufactured for extended pour purposes, clinicians should avoid storage for 6 h to pour stone casts as all studied alginate brands showed statistically significant changes in at least two of the three evaluated dimensions following storage in specified conditions before pouring.

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**Conflicts of interest**

There are no conflicts of interest.

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