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Dimensional stability of stored extended-pour irreversible hydrocolloids materials

Estabilidade dimensional de hidrocoloides irreversíveis com tempo para vazamento estendido

Estabilidad dimensional de hidrocoloides irreversibles con tiempo de vaciado prolongado

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Abstract
The purpose of this study was to evaluate the linear dimensional stability of four extended-pour irreversible hydrocolloids (EPIHs). Material and Methods: Five samples per material (Cavex ColorChange, Cavex Orthotrace, Jeltrate Plus, and Orthoprint) were prepared following the manufacturers' instructions. The samples were prepared using a cylindrical matrix coupled with a nylon-polyamide ring. Two parallel, 25-mm equidistant lines were made on its surface following ANSI/American Dental Association (ADA) Specification 18 for plaster reproducibility and compatibility and Specification 19 for linear dimensional change. The samples were stored in an environment with a relative humidity of 70% (± 3) and temperature of 28°C (± 2). Photo images were obtained using a digital camera to record images for 120 hours, with a standardized distance of 80cm between the lens and the specimen. Adobe Photoshop CS3 software was used for the measurement of the recorded images. The measurements refer to the equivalent distance between the two parallel lines printed on the samples. Data were analyzed using one-way analysis of variance (ANOVA) and Tukey's test for multiple comparisons between the means of the groups. Results: There was no statistically significant difference ($p > 0.05$) when EPIHs were compared at the same time of evaluation. Orthoprint, Cavex Orthotrace, and Cavex Colorchange presented with least dimensional stability up to 24 hours ($p > 0.05$) of storage, followed by Jeltrate Plus (48 hours). Conclusions: Storage of EPIHs for more than 24 hours for Cavex ColorChange and 48 hours for others EPIHs studied produces significant dimensional changes in the impressions stored at a humidity of 70% (± 3) and temperature of 28°C (± 2). Extended storage times produce large dimensional changes.
Keywords: Dimensional accuracy; Irreversible hydrocolloids; Impression materials.

Resumo
O objetivo deste estudo foi avaliar a estabilidade dimensional linear de quatro hidrocolóides irreversíveis de vazameto estendido (EPIHs). Material e Métodos: Cinco amostras por material (Cavex ColorChange, Cavex Orthotrace, Jeltrate Plus e Orthoprint) foram preparadas seguindo as instruções dos fabricantes. As amostras foram preparadas em matriz cilíndrica acoplada a um anel de náilon-poliamida. Duas linhas paralelas equidistantes de 25 mm foram feitas em sua superfície seguindo a especificação 18 da ANSI / American Dental Association (ADA) para reprodutibilidade e compatibilidade do gesso e a especificação 19 para mudança dimensional linear. As amostras foram armazenadas em ambiente com umidade relativa de 70% (± 3) e temperatura de 28 ° C (± 2). Imagens fotográficas foram registradas por 120 hrs, obtidas por meio de uma câmera digital, com distancia padronizada de 80cm entre a lente e o corpo de prova. O software Adobe Photoshop CS3 foi utilizado para a mensuração das imagens registradas. As medidas referem-se à distância equivalente entre as duas linhas paralelas impressas nas amostras. Os dados foram analisados por meio de análise de variância (ANOVA) e teste de Tukey para comparações múltiplas entre as médias dos grupos. Resultados: Não houve diferença estatisticamente significativa (p> 0,05) quando os EPIHs foram comparados no mesmo momento da avaliação. Orthoprint, Cavex Orthotrace e Cavex Colorchange apresentaram menor estabilidade dimensional até 24 horas (p> 0,05) de armazenamento, seguido de Jeltrate Plus (48 horas). Conclusões: O armazenamento de EPIHs por mais de 24 horas para Cavex ColorChange e 48 horas para outras EPIHs estudadas produz mudanças dimensionais significativas nas impressões armazenadas a uma umidade de 70% (± 3) e temperatura de 28 ° C (± 2). Tempos de armazenamento estendidos produzem grandes mudanças dimensionais.
Palavras-chave: Precisão dimensional; Hidrocolóides irreversíveis; Materiais de moldagem.

Resumen
El objetivo de este estudio fue evaluar la estabilidad dimensional lineal de cuatro hidrocoloides irreversibles de vertido extendido (EPIH). Material y métodos: Se prepararon cinco muestras por material (Cavex ColorChange, Cavex Orthotrace, Jeltrate Plus y Orthoprint) siguiendo las instrucciones de los fabricantes. Las muestras se prepararon utilizando una matriz cilíndrica acoplada con un anillo de nailon-poliamida. Se hicieron dos líneas paralelas equidistantes de 25 mm en su superficie siguiendo la Especificación 18 de ANSI / American Dental Associadtion (ADA) para la reproducibilidad y compatibilidad del yeso y la Especificación 19 para el cambio dimensional lineal. Las muestras se almacenaron en un ambiente con una humedad relativa del 70% (± 3) y una temperatura de 28 ° C (± 2). Las imágenes fotográficas se obtuvieron utilizando una cámara digital para grabar imágenes durante 120 horas, con una distancia estandarizada de 80 cm entre la lente y la muestra. Se utilizó el software Adobe Photoshop CS3 para la medición de las imágenes grabadas. Las medidas se refieren a la distancia equivalente entre las dos líneas paralelas impresas en las muestras. Los datos se analizaron mediante el análisis de varianza unidireccional (ANOVA) y la prueba de Tukey para comparaciones múltiples entre las medias de los grupos. Resultados: No hubo diferencia estadísticamente significativa (p> 0.05) cuando se compararon los EPIH en el mismo momento de la evaluación. Orthoprint, Cavex Orthotrace y Cavex Colorchange presentaron la menor estabilidad dimensional hasta 24 horas (p> 0.05) de almacenamiento, seguidos de Jeltrate Plus (48 horas). Conclusiones: El almacenamiento de EPIH por más de 24 horas para Cavex ColorChange y 48 horas para otros EPIH estudiados produce cambios dimensionales significativos en las impresiones almacenadas a una humedad del 70% (± 3) y temperatura de 28 ° C (± 2). Los tiempos de almacenamiento prolongados producen grandes cambios dimensionales.
Palabras clave: Precisión dimensional; Hidrocoloides irreversibles; Materiales de impresión.

1. Introduction

Irreversible hydrocolloids (IHs) are impression materials used for impression of dentogingival structures to obtain preliminary models (Cohen, et al 1995, Donovan & Chee 2004). They have advantages such as low cost and ease of handling, and they require no equipment to use, unlike other impression materials (Fellows C and Thomas G, 2009). However, traditional IHs are dimensionally unstable and offer good reproducibility of structures when they are filled with plaster immediately after impression (Cohen, et al., 1995, Chen et al., 2004). Recent changes made in these materials aimed to improve their physical and mechanical properties, such as the dimensional stability and permanent deformation (Chen et al 2004, Erbe et al., 2012, Nassar et al., 2011). Based on this perspective, these materials are called “extended-pour alginates” or “100-hour alginates.” (Todd et al., 2013) The name refers to dimensional stability; according to the manufacturer, these materials are stable for up to 120 hours after an impression is obtained (Todd et al., 2013).

One of the important physical properties of these materials is the dimensional stability, which is defined by the ability to maintain dimensional accuracy over a certain period (Todd et al., 2013, Patel et al., 2010).

The dimensional changes that may occur in IHs can interfere with the dimensional accuracy of the plaster model. Numerous researchers (Cohen, et al., 1995, Erbe et al., 2012, Todd et al., 2013, Hiraguchi et al., 2007, Hiraguchi et al., 2006, Hiraguchi et al., 2005, White et al., 2010, Martin et al, 2007) have evaluated the behavior of IHs regarding dimensional stability after they underwent disinfection by different substances and different types of storage until the plaster pouring stage.

In clinical practice, there are difficulties with respect to flexibility in pouring with plaster after completion of impressions with His (Todd et al., 2013, Martin et al., 2007, Dalstra et al., 2009). Many practitioners have no suitable material or environment for this purpose, resulting in impressions changing dimensionally in the first 24 hours (Todd et al., 2013).

Some studies (Erbe et al., 2012, Todd et al., 2013, Hiraguchi et al., 2005, White et al., 2010) evaluated the dimensional stability of these extended-pour irreversible hydrocolloids (EPIHs) stored in plastic bags or humidifiers. However, the authors were not able to specify whether these EPIHs can remain exposed to air (Imbery, et al., 2010, Garrofé et al 2015).

This lack of knowledge hampers establishment of an accurate definition of a suitable time for the impression to be poured without suffering significant dimensional changes, as it remains exposed to air (Imbery, et al., 2010). Therefore, scientific evidence is essential for professionals to be able to choose late pouring of an impression without the need to store it in a humidifier or plastic bag, resulting in lower costs for professionals and better planning time. From this perspective, laboratory studies are essential to prove dimensional stability.

In this sense, understanding the impact of these benefits can enable the exact establishment of an appropriate time to pour the impression prior to the occurrence of dimensional changes. Therefore, the aim of this study was to evaluate the dimensional changes of four EPIHs (claiming 100 hours of accuracy) when stored in relative humidity of 70% (± 3) and temperature of 28°C (± 2), through the analysis of dimensional stability after 120 hours according to Specifications 18 and 19 of ANSI/ ADA (ANSI/ADA Specification 18 and 19). The null hypothesis was that EPIHs cannot maintain dimensional stability when stored with controlled humidity and temperature at different periods of evaluation.

2. Methodology

Four EPIHs, Cavex ColorChange (Cavex Holland BV, Haarlem, CJ, Netherlands), Cavex Orthotrace (Cavex Holland BV, Haarlem, CJ, Netherlands), Jeltrate (Dentsply Caulk, Milford, DE, USA), and Orthoprint (Zhermack, Badia Polesine, RO, Italy) were prepared according to the manufacturers' instructions and then tested (Table 1).

Table 1: Materials used in the study with setting and working time recommended by manufacturers.

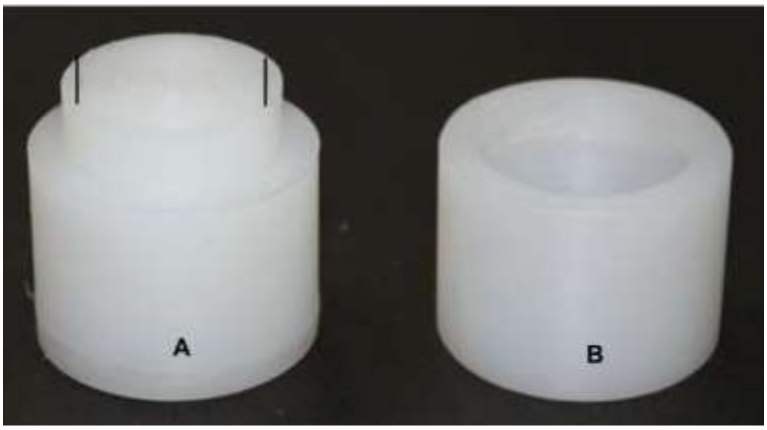
Materials	Manufacturer	Lot Number	Working time (min/s)	Setting time (min/s)
Cavex ColorChange	Cavex Holland BV, Haarlem, CJ, Netherlands	100211	1'30"	2'30"
Cavex Orthotrace	Cavex Holland BV, Haarlem, CJ, Netherlands	100305	1'10"	2'10"
Jeltrate Plus	Dentsply Caulk, Milford, DE, USA	600793D	1'30"	2'30"
Orthoprint	Zhermack, Badia Polesine, RO, Italy	123149	1'35"	2'35"

Source: Authors.

Samples preparations

The samples were prepared using a cylindrical matrix coupled with a nylon-polyamide ring fabricated with sharp scored lines that allowed for easy visualizationXS and accurate measurement directly on the impression materials (Figure 1). Two parallel and 25-mm equidistant lines were made on its surface following ANSI/ADA Specification 19 for linear dimensional change.Thus, it was possible to standardize and measure the distance between two defined points in lines D1 and D2. These points were previously marked in the matrix to obtain the impression (Figure 2 and 3)

Figure 1: A: Nylon-polyamide ring cylindrical matrix. B: Ring for coupling with the cylindrical matrix.

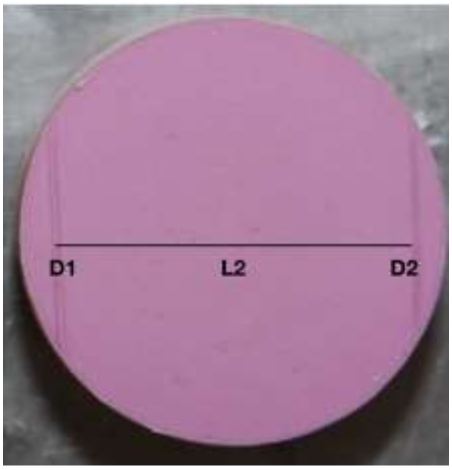


Source: Authors.

Figure 2: Nylon-polyamide with the line measured (L1) in the Adobe Photoshop CS3 software and the points to be reproduced in the IH (D1 and D2).

Source: Authors.

Figure 3: The impression of IH with the line measured (L2) in the Adobe Photoshop CS3 software and the lines reproduced from the matrix (D1 and D2).



Source: Authors.

Before preparing each sample, the matrix was immersed in water preheated to 35°C (± 1°C) for 30 minutes to simulate the oral temperature. The proportion of alginate powder and water was 22 g/50 mL (ANSI/ADA Specification 18) and mixed according to the manufacturers' instructions. After manipulation, the material was placed vertically over the sample ring, preventing the incorporation of air bubbles during the positioning of the alginate on the matrix. Subsequently, a flat glass plate was pressed over the matrix and the alginate, preventing any twisting movement during the positioning of the upper ring. A load of 1 kg was placed on the glass plate until the material and the whole set was transferred to a water bath and maintained at 35°C (± 1°C) for 5 minutes. Thus, five cylindrical samples 30 mm in diameter and 3 mm thick were obtained from each group (n = 5).

Obtaining the images

The tests were performed by only one experienced researcher, who was trained in all necessary procedures for the preparation of samples before evaluation.

The images were recorded with a digital camera (NIKON, D90 – 105-mm macro lens). The camera was coupled 80 cm away from the sample, and the images were recorded for 120 hours. Beside the sample, a 1-mm ruler was positioned to serve as a standard of measurement of the distance between the lines.

Storage of samples

The samples were kept in a Styrofoam box with controlled humidity and temperature (relative humidity of 70% [± 3] and temperature of 28°C [± 2]) between obtaining the photographs.

In the first hour, images were recorded every 10 minutes, and then the recording was performed every hour up to 48 hours of assessment. After 48 hours, the images were then recorded every 3 hours. Finally, after 94 hours of evaluation, these recordings were performed every 6 hours.

Measure of dimensional change

The measured distance on the impression was then directly compared with the true distance on the standardized die (25 mm) to determine the amount of dimensional change. For the measures, the imaging software Adobe Photoshop CS3 was used. The calculation of the dimensional change was performed according to ISO 4823 (ANSI/ADA Specification 4823, 2000), which recommends the use of the following equation to calculate the percentage of linear dimensional change: ΔL [%] = [(L2 - L1) / L1] x 100, where L1 is the distance between the lines in the matrix (D1 and D2) and L2 is the distance between the lines of alginate (D1 and D2) (Figure 3).

Statistical analysis

Data were submitted to a normality test, and one-way analysis of variance (ANOVA) was used to test the null hypotheses that (1) there would be no significant difference between the alginate groups at the same evaluation time (1, 2, 4, 6, 24, 48, 72, 100, and 120 horas) and (2) there would be no significant difference between the times evaluated within the same alginate group (Cavex ColorChange, Cavex Orthotrace, Jeltrate Plus, and Orthoprint). SPSS 24.0 (IBM, Armonk, NY, USA) was used. Analyses were performed with a 5% significance level.

3. Results

When the alginate groups were compared considering the same evaluation time, there was no significant difference in any of the comparisons ($P > 0.05$); however, there was a significant difference between the times evaluated within the same alginate group ($p < 0.001$) (Table 2). The two-to-two comparisons, performed using the Tukey test, can be observed in Table 3, taking into consideration vertical letters.

Table 2: One-way ANOVA for dimensional stability of 4 extended-pour irreversible hydrocolloids.

Variable		Sum of Squares	df	Mean Square	F	*P*
Cavex ColorChange	Between groups	85.71	53	1.617	30.70	<0.0001
	Within Groups	11.38	216	0.052		
	Total	97.09	269			
Cavex Orthotrace	Between groups	118.3	53	2.233	18.27	<0.0001
	Within Groups	26.39	216	0.122		
	Total	144.7	269			
Jeltrate Plus	Between groups	194.9	53	3.678	11.85	<0.0001
	Within Groups	67.02	216	0.310		
	Total	262.0	269			
Orthoprint	Between groups	114.3	53	2.157	29.79	<0.0001
	Within Groups	15.64	216	0.072		
	Total	130.0	269			

Source: Authors.

Table 3: Mean values (standard deviation) of dimensional change of the samples in different evaluation periods.

Time	Cavex ColorChange	Cavex Orthotrace	Jeltrate Plus	Orthoprint
1h	25.10 (0.05) ^{A}	24.99 (0.08) ^{A}	25.11 (0.12) ^{A}	25.03 (0.03) ^{A}
2h	25.05 (0.05) ^{A}	24.85 (0.15) ^{A}	25.00 (0.15) ^{A}	24.85 (0.14) ^{A}
4h	24.92 (0.08) ^{A}	24.77 (0.08) ^{A}	24.96 (0.13) ^{A}	24.85 (0.14) ^{A}
6h	24.87 (0.09) ^{A}	24.72 (0.08) ^{A}	24.92 (0.16) ^{A}	24.78 (0.17) ^{A}
24h	24.33 (0.16) ^{B}	24.08 (0.27) ^{B}	24.32 (0.30) ^{A}	24.10 (0.20) ^{B}
48h	23.76 (0.25) ^{B}	23.37 (0.47) ^{B}	23.37 (0.37) ^{B}	23.44 (0.35) ^{B}
72h	23.68 (0.24) ^{B}	23.21 (0.54) ^{B}	23.06 (0.69) ^{B}	23.38 (0.38) ^{B}
100h	23.32 (0.50) ^{B}	23.03 (0.50) ^{B}	22.80 (0.05) B	23.16 (0.41) ^{B}
120	23.06 (0.69) ^{B}	22.94 (0.64) ^{B}	22.80 (0.05) B	22.90 (0.78) ^{B}

Different vertical letters = significant difference, $p < 0.05$. Source: Authors.

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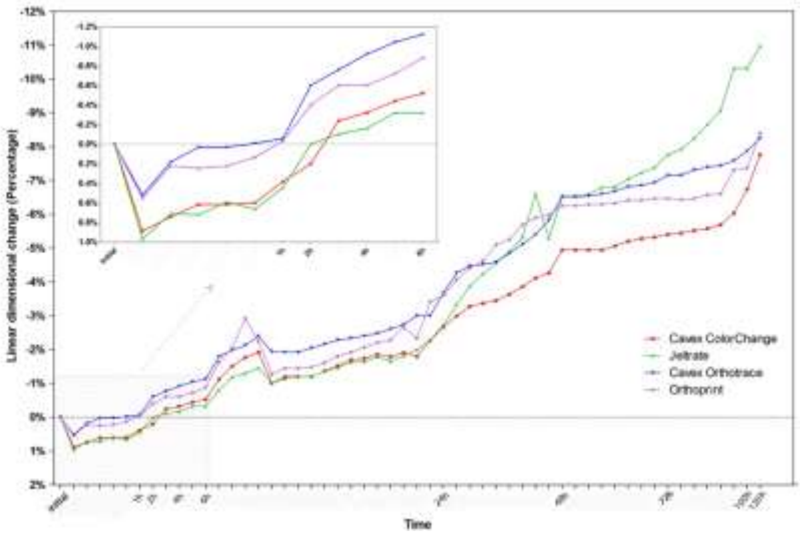
The one-way ANOVA statistical analysis revealed a significant difference in the different periods ($P < 0.0001$) independent of the material applied (Table 2). The dimensional stability of the samples decreased with storage time (Table 3). The largest difference between the means of the initial (baseline) and final evaluations (106 hours) was found in Jeltrate Plus (25.00–22.80 mm), followed by Orthoprint (25.00–22.90 mm), Cavex Orthotrace (25.00–22.94 mm), and Cavex Colorchange (25.00–23.6 mm).

Cavex Colorchange, Cavex Orthotrace, and Orthoprint exhibited a period of dimensional stability, showing no statistically significant difference up to 24 hours ($p > 0.05$) of evaluation, followed by Jeltrate Plus (48 hours) (Table 3).

The ΔL values from 0.1 to 0.8% are clinically acceptable according to the literature. Therefore, the formula provided in ANSI/ADA Specification 19[19] was used to compare the linear dimensional change, where the Cavex Orthotrace exhibited ΔL between 0.1 to 0.8% until 3 hours of evaluation, and other materials presented this range until 6 hours of evaluation (Figure 4). When analyzed after 120 hours, materials showed high ΔL%, between 7 and 10%.

Figure 4: Linear dimensional change of EPIHs exposed to air up to 120 hours.



Source: Authors.

4. Discussion

It is crucial that IHs are accurate with respect to dimensional stability for producing plaster models models (Cohen, et al 1995, Donovan and Chee 2004, Nassar et al., 2011). Some of the factors that influence the accuracy of IHs are the time and storage condition until the pouring time (Nassar et al., 2011, Todd et al., 2013, Patel et al., 2010, Martin et al., 2007, Walker et al 2010). This study investigated the influence of EPIH storage in relative humidity of 70% (± 3) and temperature of 28°C (± 2) through the analysis of dimensional stability for up to 106 hours. The results indicate that the null hypothesis should be rejected in part because the dimensional changes of EPIHs were affected by storage in relative humidity of 70% (± 3) and temperature of 28°C (± 2) in some time intervals.

The samples were prepared according to the manufacturers' instructions and following the standards of ANSI/ADA Specification 18 (ANSI/ADA Specification 18) for reproducibility and compatibility of plaster, and Specification 19 (ANSI/ADA Specification 19) for linear dimensional change. The tests were performed by only one experienced researcher, after being trained on all necessary procedures for the preparation of samples before evaluation.

Prolonged storage of conventional IHs is contraindicated by many authors (Erbe et al., 2012, Nassar et al.,2011, Todd et al., 2013, Patel et al., 2010, Martin et al., 2007, Imbery et al., 2010, Erickson et al., Garrofé et al., 2015), as they suffer clinically unacceptable dimensional changes. These contractions occur due to syneresis, or loss of water. The syneresis can be described as the aging process of gel formation. It is a continuation of the same reactions that caused the gel to form initially. As a result, the network of interlinked molecules constricts and the water is expelled from the interstitial spaces between alginate chains (Todd et al., 2013). The macroscopic result is the contraction of the material. Therefore, according to several studies (Erbe et al., 2012, Todd et al., 2013, Patel et al., 2010, Imbery et al., 2010, Walker et al., 2010) conventional IHs must be immediately stored in tightly sealed plastic bags or in humidifiers and poured as soon as possible.

On the other hand, EPIHs were introduced in the market to prolong storage time until pouring (Erbe et al., 2012). Studies (Erbe et al., 2012, Nassar et al.,2011, Todd et al., 2013, Patel et al., 2010, Imbery et al., 2010, Rohanian et al 2014) have reported that some of these EPIHs can remain stored in tightly sealed plastic bags up to 5 days. Specification 18 of the ADA (ANSI/ADA Specification 18) does not stipulate the maximum ΔL acceptable for IHs. However, ADA Specification 19 (ANSI/ADA Specification 19) indicates the maximum acceptable percentage of ΔL of polysulfates up to 0.40 and 0.60, respectively. Although there is no definition of the maximum ΔL allowable for IHs, some authors (Cohen et al 1995, Chen et al 2004, Erbe et al., 2012) indicate clinically acceptable ΔL values for IHs that are between 0.1 and 0.8%. Therefore, the materials evaluated in this study had clinically acceptable values up to 6 hours, with the exception of Cavex Orthotrace, which remained acceptable until 3 hours of storage. This indicates that during this period, if the impression is kept in humidity of 70% (± 3) and temperature of 28°C (± 2), accurate plaster models can be obtained.

Figure 3 shows the behavior of the studied materials, and the dimensional change increases with the storage time. In the first 10 minutes, an increase of the impression occurred; later, there was a progressive increase in the shrinkage of the material. This might have occurred initially due to the imbibition phenomenon; the material absorbed the water product of the mixture and the water in which it was immersed. Later, the phenomenon of syneresis occurred, where the material began to lose water progressively, influenced by the temperature and form of storage (Imbery et al 2010).

Although they used different forms of storage for EPIHs, Erbe et a.l found results close to those found in this study. They used humidifier storage, which allowed accurate leakage of the impressions up to 4 hours, while storage in a bag/tissue facilitated precise impressions in 2 hours. The material was time dependent: The higher the storage time, the greater the dimensional change of the EPIHs. Differently, Imbery et al 2010 obtained accurate models within 48 hours after impression when two EPIHs were used. These results were obtained when the impressions were stored in plastic zipper storage bags at room temperature (23°C). Differences in the behavior of the materials in the study may be due to the way the materials were stored.

It can be observed that no material presented clinically acceptable ΔL after 48 hours of storage. This demonstrates that for dentists to obtain optimum dimensional stability, EPIH impressions should be poured as soon as possible, because in general, mean values increase with time.

The findings of this study were based on storage of EPIHs under specified conditions of humidity (70% [± 3]) and temperature (28°C [± 2]); therefore, they should not be extrapolated to other conditions. Todd et al 2013, also evaluated the dimensional changes of EPIHs with storage in sealed plastic bags at 3 different temperatures (23ºC, 46ºC, and -9ºC). The authors concluded that the materials suffered negative influences in extreme temperature conditions. Therefore, EPIHs showed significant growth when stored at high temperature, caused by the expansion of the water content (the thermal expansion coefficient of pure water is 0.0001–0.0004 per 1ºC in temperatures between 10ºC and 50ºC). However, the contraction was higher when EPIHs remained stored at low temperature because the water turned to ice inside the alginate matrices.

Although manufacturers recommend up to 5 days pouring time for EPIHs, this study showed significant dimensional changes for times of more than 24 and 48 hours, and this behavior was found in several studies in the literature Erbe et al., 2012, Nassar et al.,2011, Todd et al., 2013, Patel et al., 2010, Tood et al., 2012, Sharif et al., 2021, Bitencourt et al., 2021). Other studies showed significant dimensional change from 72 hours onwards (Porrelli, et al., 2020)

The limitation of this study is that the samples were prepared in conditions of controlled temperature and humidity, whereas in the day to day of clinics, most of the time, temperature, humidity, and form of storage are not controlled. In short, dentists may forego EPIH storage when opting for pouring after a short period under favorable conditions (temperature and humidity).

5. Conclusion

The storage of EPIHs for more than 24 hours for Cavex ColorChange and 48 hours for others EPIHs produces significant dimensional changes in the impressions stored at a humidity of 70% (± 3) and temperature of 28°C (± 2). Extended storage times result in large dimensional changes.

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