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Original article

Dimensional Accuracy of Two Impression Materials Regarding Impression Technique and Pouring Time Using Cone Beam Computed Tomography Analysis

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Abstract
An ideal impression material should present with dimensional stability over long periods, allowing the precise production of cast models at any time. However, the materials commonly used in dental impressions present alterations in their dimensional behavior. This study amid to evaluates the effect of the Impression technique, Single step, two steps, and Impression pouring time on the dimensional accuracy of two different impression materials; polyvinyl siloxane impression material, and polyether impression material, using Cone Beam Computed Tomography (CBCT) analysis. Two commercially available impression materials were used in this study Polyvinyl siloxane (PVS)- Polyether (PE),30 standardized metal custom-made dies representing full veneer all ceramic crown preparation, and 30 perforated custom-made trays fabricated that be placed in the same position on the master die for each impression, each material divided into two groups each group (n 15)one group using two-step technique the other group one step technique For each group, specimens were subdivided according to the pouring time into three subgroups (5 samples); 1hour, 24hour, 7days. All samples submitted for CBCT for evaluation of their dimensions. There were no significant differences with PVS and PE, but the single step showed a significant difference in highest mean high compared to two steps. 1 hr. (4.96±0.01 μm) showed an insignificant difference on mean height compared to 24 hours (4.96±0.01 μm) and 7 days (4.90±0.01 μm) at p=0.791 for Single step.1 hr (4.86±0.01 μm) showed insignificant difference on mean height compared to 24 hours (4.85±0.01 μm) and 7 days (4.81±0.01 μm) at p=0.960 for Two steps for PVS. 1 hr (4.95±0.03 μm) showed insignificant difference on mean height compared to 24 hours (4.94±0.01 μm) and 7 days (4.89±0.01 μm) at p=0.100 for Single step. 24 hours (4.85±0.02 μm) showed significant difference on mean height compared to 1 hr (4.84±0.01 μm) and 7 days (4.80±0.01 μm) at p≤0.001 for two steps for PE. Polyvinyl siloxane and poly ether materials give high accurate stone dies. One-step impression taking technique give more accurate stone dies than the two-step technique. pouring time is very critical for PE impression materials.
Keywords. Polyvinyl Silicone, Impression Material, Poly Ether, Cone Beam Computed Tomography.

Introduction
Elastomers are rubber-based materials used for dental impressions that can be classified into four groups according to the polymer constituent, Poly sulfide, polyether, polyvinyl siloxane, and condensation silicone. An ideal impression material should present, among other characteristics, dimensional stability over long periods, which allows the production of precise cast models at any time. However, the materials commonly used in dental impressions present alterations in their dimensional behavior. The release of water and ethanol as by-products of the polymerization of polysulfide and condensation silicone, respectively, and polyether hydrophilic behavior may affect their dimensional stability. Due to the absence of by-products in PVS polymerization, it presents the most favorable dimensional behavior [1-5]. The dimensional changes of the impression materials may affect the quality of fit and retention of dental prostheses, which influence the success of indirect restorative procedures [4,6-10].
The dimensional behavior of impression material is influenced by the time interval from mixing to pouring, the thickness of the layer of material in the tray [8, 12], and the type of polymer comprising the elastomers [11,13]. The impression technique can be performed using single or double steps, which can lead to different outcomes concerning dimensional accuracy [14,15]. Polyether has properties such that it can flow into critical areas is moderately hydrophilic and captures accurate impressions in the presence of some saliva or blood. Because their wetting angle is low, they capture a full arch impression more easily than with polyvinyl siloxanes. Their ability to reproduce detail is excellent and they are dimensionally stable and allow multiple pours of accurate casts for 1 to 2 weeks after impressions are made. They do not tear easily, which enables the dentist to get good sub gingival detail without tearing the impression on removal [16,17].
Addition silicones are the most popular because no reaction by-products are formed. Its reaction involves the linking of a vinyl siloxane in the base material with a hydrogen siloxane via a platinum catalyst [16,1].

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Vinyl polysiloxane silicones are considered state-of-the-art for fixed partial denture impressions. They constitute the most widespread use of impression materials for fixed prosthetics [1]. Some polyvinyl siloxane materials exhibit a phenomenon known as hydrogen out-gassing, if you pour casts too soon the stone captures these bubbles and produces a cast with pitted areas. The newer materials are said to contain a proprietary component that eliminates hydrogen bubbles, but it is best to read the guidelines for pouring specific brands of polyvinyl siloxanes before pouring stone [18,19]. When considering the replication process of which impression making is a part, an understanding of the accuracy required of an impression material is important. The accuracy of the material has been evaluated as a function of the time of pouring and repeat pouring of the models [20-24]. The conditions under which the materials are stored [25], the effect of temperature as a variable [26], the tear strength of the material [27], the requirement that the set impression is disinfected, and finally the impression technique used are also factors to affect the accuracy [28].
Impression techniques can be categorized as a monophase or dual phase. Techniques that use dual-phase materials such as the putty and light-body may be accomplished in one or two steps. A two-step impression technique has been used to compensate for the shrinkage of the impression material [28]. A preliminary impression is usually made with a very high viscosity material putty and used as a tray, and then the final impression using a low viscosity impression material is employed. This technique has the potential to lessen the polymerization shrinkage [29,30], however, it takes longer time, compared to a one-step impression technique. The one-step putty/light-body technique requires less chair-side time but produces incorrect impressions due to rapid polymerization and poor flow [31-33], although the literature reported no significant difference with the two-step impression [34-36].
Cone Beam Computed Tomography (CBCT) and radiology are important in the diagnostic assessment of the dental patient and guidelines for the selection of appropriate radiographic procedures for patients suspected of having dental and maxillofacial disease are available. The introduction of CBCT for the maxillofacial region provides opportunities for dental practitioners to request multiplane imaging. Most dental practitioners are familiar with the thin-slice images produced in the axial plane by conventional helical fan-beam CT. CBCT allows the creation in “real-time” of images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal, and even oblique or curved image planes a process referred to as multiplane reformation (MPR). In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information [37,38].
Application of CBCT Imaging to Clinical Dental Practice Unlike conventional CT scanners, which are large and expensive to purchase and maintain, CBCT is suited for use in clinical dental practice where cost and dose considerations are important, space is often at a premium and scanning requirement are limited to the head. All CBCT units initially provide correlated axial, coronal, and sagittal perpendicular MPR images. Basic enhancements include zoom or magnification and visual adjustments to narrow the range of displayed grey scales (window) and contrast levels within this window, the capability to add annotation, and cursor-driven measurement [38]. This study aimed to evaluate the effect of impression technique, single step, two steps, and impression pouring time on the dimensional accuracy of two different impression materials, Polyvinyl siloxane impression material and Polyether impression material using Cone beam computed tomography (CBCT) analysis.

Methods

Two commercially available impression materials were used in this study as shown in table (1). Dental die stone is ideal for all kinds of prosthetics, with high precision, hardness, and high-pressure stability. precise model for prosthetics is achieved. It has excellent physical properties, short mixing time (about 1 minute), fast and easy to use, extended working time (over 8 minutes), short setting time (only 12 minutes), and removable from cast after just 30.

Table 1. Product overview

Product	Lot number	Type of material	Viscosity	Manufacturer
Imprint II Garant	20090403	Polyvinyl siloxane (VPS)	heavy	3M ESPE AG, Seefeld-Germany
	20080605	Polyvinyl siloxane (VPS)	Light	3M ESPE AG, Seefeld-Germany
Impregum	320474	Polyether (PE)	Heavy	3M ESPE AG, Seefeld-Germany
	357021	Polyether (PE)	Light	3M ESPE AG, Seefeld-Germany

A custom-made master die, representing all ceramic crown preparation was constructed for impression-

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making standardization. A perforated custom-made tray was fabricated that could be placed in the same position on the master die for each impression. The metal master die was prepared by a milling machine to resemble a prepared tooth with 5mm height and 5mm width at the base, the occlusal taper was 6°and 1mm shoulder finish line (Figure 1).

Figure 1. Metal master die

The die has a 24mm diameter base to ensure proper handling. Each custom-made perforated tray was cylindrical with an inner diameter 7mm (to accommodate the base of the mater die) and an inner height of 9mm was made to act as a tray for accommodating the impression materials [39] (Figure 2).

Figure 2. Custom made perforated metal tray

Table 2. Samples grouping

Material	**Polyvinyl siloxane (PVS)**		**Polyether (PE)**	
Technique Pouring time	Group 2 Two steps (2)	Group 1 Single step (1)	Group 2 Two steps (2)	Group 1 Single step (1)
5 A 2	5 A 1	5 A 2	5 A 1	(Sub group A) After 1 hour
5 B 2	5 B 1	5 B 2	5 B 1	(Sub group B) After 24 hours
5 C 2	5 C 1	5 C 2	5 C 1	(Sub group C) After 7 days

Impression techniques, single step impression technique, for the PVS impression material, the heavy-bodied material was injected using mixing plastic tips of the auto-mixing gun to the custom-made perforated trays. At the same time, the light-bodied material was injected by another tip of the auto-mixing gun on the die. The polyvinyl siloxane impression had a working time of 3 minutes and a total setting time of 6 minutes [40]. The impression tray was then centered over the die and seated till the tray are completely fit into the handling base of the die. Initially, finger pressure was applied to allow accurate seating and escape of excess material. Then, trays were steadily held with a c-shaped clamp till polymerization and setting were completed [39,40]. The impression was allowed to be set for 4 minutes longer than the manufacturer's recommended minimal removal time as indicated in ADA specification 19 for laboratory testing [39].
The two-step impression technique was used for the heavy-bodied impression materials plus the light viscosity layer, the heavy-bodied material was injected by the special tip (of their auto mixing gun) into the

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custom-made perforated tray [39], and the impression tray was then centered over the die and seated till the tray was completely fit into the handling base of the die. Initially, finger pressure was applied to allow accurate seating and the escape of any excess material. Then, trays were steadily held with a c-shaped clamp with no applied pressure till polymerization and setting were completed [4]. After complete setting, the tray was removed from the die in sharp snap removal parallel to the long axis of the die with fingertips. The light-bodied impression was then loaded and injected around the metal die, the tray was reseated on the die and the same procedures were then followed as before [40,41]. All impressions were stored at room temperature (20°c) and then poured with stone type IV according to pouring time (1h,24hrs, 7 days). A 10 ml of distilled water was placed in the mixing bowl of the vacuum mixer. A 100 g of type IV dental stone was placed inside the bowel and hand mixed for 10 sec to ensure complete wetting of the powder then mixed mechanically under vacuum for 30 sec. in a vacuum mixing machine. After mixing was completed, the stone mix was introduced inside the impression by a thin probe while the impression was placed on a vibrator to prevent air entrapment until the impression was filled, then the rest of the mix was poured into a rubber base former over which the impression tray was placed to make a standard base for each cast every time [42]. The stone was allowed to set for 30 min. before being retrieved from the impressions. The dimensions of stone dies were measured after retrieval from the impressions, and all measurements were made by the same operator. All produced cast models were trimmed to facilitate their placement during testing (Figure 3).

Figure 3. Stone dies

Measurements of the dimensional accuracy (radiographic analysis), all samples submitted for CBCT for evaluation of their dimensions, and CBCT images were acquired using a Next Generation I-CAT scanner (Imaging Sciences International, Inc., Hatfield, USA). A scout view was obtained and adjustments were made to ensure that all samples were correctly aligned in the scanner according to the adjustment light beam before acquisition. Measurement of height, At the section module, sagittal and coronal reference lines were brought to intersect at the center of the die to be evaluated (Figure 4). Then, using the reorientation tool, the volume was readjusted to oblige the coronal and sagittal lines to be parallel to the long axis of the die. The two reference lines were finally ensured to intersect at the center of the die at the axial view. The height of the die was measured at the produced sagittal and coronal views, where measurement was made by drawing a line from the highest point of the die to a line previously drawn tangential to the base of the finish line. Measurement was taken at coronal and sagittal views in five different levels.

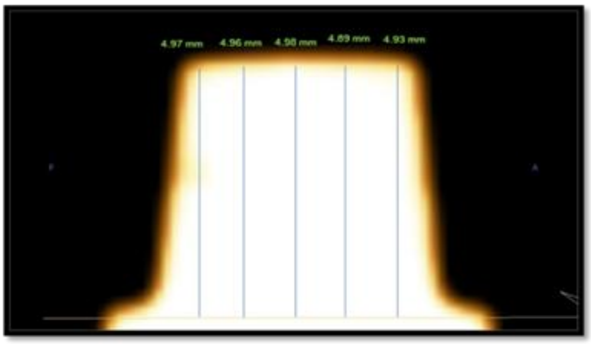

Figure 4. Measurement of height

Data collection procedure

Multivariate analysis of variance was used to gather, tabulate, and analyze the data using SPSS software

Results

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Mean and standard deviation (SD) for the Height (µm) for different Impression materials regardless of other variables were presented in table (3). PVS (4.91±0.05µm) showed an insignificant difference with PE (4.89±0.05µm) at p=0.983.

Table 3. Height (µm) for different impression materials

Variable	Impressions material				p-value
	PVS		PE		
	Mean	SD	Mean	SD	
Mean height (µm)	4.91	.05	4.89	.03	0.983 NS

**= Significant, NS=non-significant*

Effect of different impressions technique on mean Height at single step (4.93±0.02 µm) showed significant highest mean height compared to two step (4.84±0.01 µm) at p≤0.001.

Table 4. Height (µm) for different impressions technique

Variable	Impressions technique				p-value
	Single step		Two steps		
	Mean	SD	Mean	SD	
Mean height (µm)	4.93	.02	4.84	.01	≤0.001*

**= Significant, NS=non-significant*

Effect of different pouring time on mean Height (µm) after1 hr (4.91±0.06 µm) showed insignificant difference on mean height compared to 24 hours (4.91±0.05 µm) and 7 days (4.89±0.01 µm) at p=0.748.

Table 5. Height (µm) for different pouring time

Variable	Pouring time						p-value
	1 hr		24 hrs		7 days		
	Mean	SD	Mean	SD	Mean	SD	
Mean height (µm)	4.91	.06	4.91	.05	4.89	.05	0.748 NS

**= Significant, NS=non-significant*

Effect of different pouring time on mean height showed that PVS at 1 hr (4.96±0.01 µm) showed insignificant difference on mean height compared to 24 hours (4.96±0.01 µm) and 7 days (4.90±0.01 µm) at p=0.791 for Single step. For Two steps, 1 hr (4.86±0.01 µm) showed insignificant difference on mean height compared to 24 hours (4.85±0.01 µm) and 7 days (4.81±0.01 µm) at p=0.960. While, PE at1 hr (4.95±0.03 µm) showed insignificant difference on mean height compared to 24 hours (4.94±0.01 µm) and 7 days (4.89±0.01 µm) at p=0.100 for Single step. For two steps, 24 hours (4.85±0.02 µm) showed significant difference on mean height compared to 1 hr (4.84±0.01 µm) and 7 days (4.80±0.01 µm) at p≤0.001

Table 6. Height (µm) for different pouring time within each impression materials and impressions technique

Variable			Pouring time						p-value
			1 hr		24 hrs		7 days		
			Mean	SD	Mean	SD	Mean	SD	
Mean height (µm)	PVS	Single step	4.96	.01	4.96	.01	4.90	.01	0.791 NS
		Two steps	4.86	.01	4.85	.01	4.81	.01	0.960 NS
	PE	Single step	4.95	.03	4.94	.01	4.89	.01	0.100 NS
		Two steps	4.85	.01	4.84	.02	4.80	.01	≤0.001*

**= Significant, NS=non-significant*

Discussion

The transfer of an accurate replication of the patient's hard and soft tissue to the dental laboratory is of critical importance in the fabrication of a fixed or a removable restoration. Making a definitive impression is a critical step in producing biologically, mechanically, functionally, and esthetically acceptable restorations [12]. The ability to produce a smooth surface and accurate detail on stone models is one of the most important factors for the impression used in fixed prosthodontics [43]. Many variables affect the ability of the impression materials to perform accurate and dimensionally stable impressions, starting from the effect of the impression material itself, the impression technique, and the pouring time. Elastomeric impression materials are used for reproducing oral conditions to construct restorations [44].

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Polyether and vinyl polysiloxane impression materials have become extremely popular during the last decade. The impression materials tested in this study represent the different possibilities encountered in the dental market aiming to provide information about the appropriate material which produces the most accurate impressions with full detail reproduction. There is much discussion in the dental literature regarding the effect of the accurate fit of cast restorations. The dual-phase impressions can be made with either the single-step impression technique or the two-step impression technique. Craig [16] stated that the choice of the technique was the more critical factor. The dual-phase impression technique was used as it is the accepted optimum technique most commonly used in general dental practice as evidenced by Jonson and Craig [23], and Wassell et al [4]. The superiority of the dual-phase impression technique in the accuracy and detail reproduction may be due to the use of the light-bodied consistency of the impression material which can flow easily and record more fine details [2].

Single step technique, in which both materials polymerize simultaneously, reduces chair side time and saves impression material. Although time is a limiting factor since the professional has to accommodate both low and high-consistency materials simultaneously before the setting occurs, this technique yields accurate impressions independently of the curing kinetics of the syringed material alone [41,45]. According to the literature, the single-step technique with polyvinyl siloxane and polyether lead to very accurate impressions. [29] In the two-step technique, a high-viscosity material is used for a preliminary impression**,** while the final impression is performed with a lower-viscosity material. Even though the two-step techniques have been widely adopted and can offer good accuracy. Some problems may be experimented with this technique, such as dimensional alternations [29,30] extra chair side time, and extra material needed. In a typical fixed prosthodontics treatment accuracy of the prosthesis is critical as it determines the success, failure, and prognosis of treatment including abutment. This is mainly depending upon fit of the prosthesis which in turn depends on the dimensional accuracy of dies, poured from elastomeric impressions. Therefore, deciding on the exact moment of pouring stone dies is an important step during the fabrication of dental prostheses.

A delay in pouring will allow the material to recover elastically after being separated from the retentive areas of the mouth. Additionally, a delay may be necessary to permit the release of by-products that can influence the accuracy of the stone dies [46]. The method selected for measuring the dimensional accuracy in this study was based on making impressions for a master model using techniques and pouring time. The dimensions of stone models poured from these impressions were then directly measured and compared with those of the master model. First, the same water/powder ratio was used for pouring all impressions. In addition, using mechanical mixing standardized the mixing time and rate which was reported to affect the amount of stone expansion [16]. Measuring the stone models was always made 24 hours after pouring the impression to ensure that any dimensional changes in the casts caused by stone setting expansion or stone dehydration shrinkage would be standardized throughout the study [24]. In the present investigation, the metal die models were used because they simplified the precise determination of the diameter and height of the resulting casts.

Standardizing the thickness of the impression material was important because the amount of polymerization shrinkage was found to be directly proportional to the thickness of the impression material [24]. To ensure customization and provide equal thickness of impression materials, all of the impressions were made in custom-made perforated metal trays. This in vitro study suggests that the impression technique can be a significant factor in determining the accuracy of the impressions. Here, to reduce the number of factors that could have influenced the outcome, costume trays were used for all of the groups, and the same operator made all impressions. Nevertheless, there were noted differences in terms of accuracy among the different techniques [33].Cone-beam computed tomography (CBCT), Most dental practitioners are familiar with the thin-slice images produced in the axial plane by conventional helical fan-beam CT. CBCT allows the creation in "real-time" of images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal, and even oblique or curved image planes — a process referred to as multi-planar reformation (MPR). In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information [38].

The results of this study revealed that the type of materials did not affect the die accuracy; as both materials don't produce any by-product during their setting reaction on condition that they are properly mixed according to manufacturer instructions This goes with the finding of Franco in 2011 [47]. This disagreement with Georgia in 1991 [48]. The results revealed the great effect of impression-taking techniques on the resulting stone die, as the stone die had greater height and diameter measures than the metal die. The one-step technique gave a more accurate stone die than the two-step technique. Because the heavy-bodied consistency is likely to produce fewer discrepancies in comparison to the light-bodied material because it contains a higher concentration of fillers than the light-body consistency. When the one-step double impression technique is used, like in the present study, the layer of the light-bodied material is usually thin, so less polymerization shrinkage, and consequently it has an insignificant influence on the accuracy of the impression. This is an agreement with Franco in 2011 [47].

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The results of this study showed a significant effect of pouring time on die accuracy, the results showed that the PVS and PE depending on pouring time. At very short pouring times, the results for the two impression materials are similar. When pouring is delayed for more than 7 days, the dimensional accuracy of polyvinyl siloxane and polyether impression materials was found to be significantly affected more than pouring after 1 hour and 24 hours. This may be due to the polyvinyl siloxane impression material being predominantly hydrophobic and does not absorb water during the storage period. This may explain the little dimensional alteration. On the other hand, polyether impression material releases volatile substances, the smell of even well-cured impregum may be an indicator of this assumption. Also, polyether is susceptible to water uptake that may affect its dimensional accuracy if poured after 24 hours this goes in agreement with Franco in 2007 [49]. who investigated the effect of the storage period on the accuracy of elastomeric impression material. The impressions were poured after 2 hours, 24 hours, and 7 days. They concluded that storage may significantly affect the dimensional accuracy of impressions and, thus, a maximum period and storage condition should be specified for the recently developed materials.

Conclusion

We concluded that polyvinyl siloxane and poly ether materials give high accurate stone dies. One-step impression taking technique give more accurate stone dies than the two-step technique. Moreover, pouring time is very critical for PE impression materials.

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Conflicts of Interest

The authors declare no conflicts of interest.

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المستخلص
يجب أن تتميز مادة الطباعة المثالية بثبات أبعادي لفترات طويلة، مما يسمح بالإنتاج الدقيق للنماذج المصبوبة في أي وقت. ومع ذلك، فإن المواد المستخدمة بشكل شائع في طبعات الأسنان تظهر تغييرات في سلوكها البعدي. تهدف هذه الدراسة إلى تقييم تأثير تقنية الطباعة والخطوة الواحدة والخطوتين ووقت صب الطباعة على الدقة البعدية لمادتين مختلفتين للطباعات؛ مادة طباعة بولي فينيل سيلوكسان، ومادة طباعة بولي إيثر، باستخدام تحليل التصوير المقطعي المخروطي الشعاعي . تم استخدام مادتين تجاريتين للطباعات في هذه الدراسة بولي فينيل سيلوكسان-بولي إيثر ، و30 قالبًا معدنيًا قياسيًا مخصصًا يمثل تحضير التاج الخزفي الكامل، و30 صينية مثقبة مخصصة الصنع توضع في نفس الموضع على القالب الرئيسي. لكل طباعة، كل مادة مقسمة إلى مجموعتين كل مجموعة (ن 15) مجموعة تستخدم تقنية الخطوتين والمجموعة الأخرى بتقنية الخطوة الواحدة لكل مجموعة، تم تقسيم العينات وفقًا لوقت الصب إلى ثلاث مجموعات فرعية (5 عينات)؛ ساعة واحدة، 24 ساعة، 7 أيام. جميع العينات المقدمة للتحليل التصوير المقطعي المخروطي الشعاعي لتقييم أبعادها. لم تكن هناك فروق ذات دلالة إحصائية مع بولي فينيل سيلوكسان وبولي إيثر ، لكن الخطوة الواحدة أظهرت فرقًا كبيرًا في أعلى متوسط ارتفاع مقارنة بخطوتين. أظهرت ساعة واحدة (4.96 ± 0.01 ميكرومتر) فرقًا ضئيلًا في متوسط الارتفاع مقارنة بـ 24 ساعة (4.96 ± 0.01 ميكرومتر) و 7 أيام (4.90 ± 0.01 ميكرومتر) عند 0.791 = p للخطوة الواحدة. أظهرت ساعة واحدة (4.86 ± 0.01 ميكرومتر) فرقًا ضئيلًا في متوسط الارتفاع مقارنة بـ 24 ساعة (4.85 ± 0.01 ميكرومتر) و 7 أيام (4.81 ± 0.01 ميكرومتر) عند p = 0.960لخطوتين لبولي فينيل سيلوكسان .أظهرت ساعة واحدة (4.95 ± 0.03 ميكرومتر) فرقًا غير مهم في متوسط الارتفاع مقارنة بـ 24 ساعة (4.94 ± 0.01 ميكرومتر) و 7 أيام (4.89 ± 0.01 ميكرومتر) عند 0.100 = p للخطوة الواحدة. أظهرت 24 ساعة (4.85 ± 0.02 ميكرومتر) فرقًا كبيرًا في متوسط الارتفاع مقارنة بساعة واحدة (4.84 ± 0.01 ميكرومتر) و 7 أيام (4.80 ± 0.01 ميكرومتر) عند 0.001 ≥ p لخطوتين لبولي إيثر .تعطي مواد بولي فينيل سيلوكسان وبولي إيثر قوالب حجرية عالية الدقة. تعطي تقنية أخذ الانطباع بخطوة واحدة قوالب حجرية أكثر دقة من تقنية الخطوتين. وقت الصب مهم للغاية لمواد طباعة بولي إيثر.

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