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IMPACT OF STORAGE DURATIONS ON VARIOUS ALGINATE DENTAL IMPRESSION MATERIALS

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Abstract

Background: Alginate impression materials are widely used in dentistry due to their ease of manipulation and cost-effectiveness; however, their dimensional stability is highly susceptible to water diffusion, evaporation, and chemical interactions within the material matrix. Variations in thickness and storage time can significantly influence weight loss and, consequently, impression accuracy. This study evaluated the dimensional stability and weight changes of two commercially available alginates Tropicalgin and Blueprint Cremix and one experimentally formulated alginate when stored in air over different time intervals.

Methods: Three alginate materials (two commercial and one experimental) were tested using standardized metal molds of 1 mm and 3 mm thickness. A total of 36 samples were prepared following manufacturers' recommendations for mixing and setting. After initial weighing, samples were stored in air at 23 °C ± 1 and reweighed at 10 minutes, 30 minutes, and 1 hour. Weight loss (%) was calculated to assess dimensional change. Data were analyzed using one-way ANOVA with a significance level of $p < 0.05$.

Results: All three materials exhibited progressive weight loss with increased storage time. Across all intervals, 1 mm samples demonstrated approximately double the weight loss observed in 3 mm samples, indicating a strong influence of material thickness on water retention. At 1 hour, weight loss in 1 mm samples ranged from 14.47% to 18.26%, whereas 3 mm samples showed an average reduction of around 8%. Among the materials tested, the experimentally formulated alginate consistently demonstrated the least dimensional change at all time points.

Conclusion: Storage time and material thickness significantly influence the dimensional stability of alginate impression materials. The experimental alginate formulation exhibited superior stability, with the lowest weight loss across all conditions. Although all alginates showed measurable contraction over time, thicker samples retained moisture more effectively, underscoring the importance of minimizing delays between impression making and model pouring in clinical settings.

Keywords: Alginate, Dimensional stability, Dental impression materials, Hydrocolloid.

INTRODUCTION

As alginates are hydrophilic, they absorb water when submerged in liquids due to changes in their osmotic potential, which causes swelling.[1] The osmotic potential may be reversed by eluting the water-soluble salts included in the alginates' matrix, which causes the water to diffuse out and the substance to shrink.[2] Alginates are particularly prone to unanticipated deformation during immersion in liquids since the resultant process takes place concurrently. This may result in reduced impression accuracy, which might negatively impact clinical results.[1] Sodium or potassium compounds are often used in alginate formulations to provide high reproducibility of imprint at the contact with storage medium. It has previously been noted that magnesium oxide (MgO) functions as a cross-linker agent in dental alginates. There is still strong evidence that magnesium oxide (MgO) plays a significant part in chemical reactions that raise pH during the settling process.[2]

Alginate, a biomaterial used in many biomedical applications, is a naturally occurring polysaccharide that is derived from brown algae, commonly known as seaweeds, such as Lesonia and Laminaria hyperborean.[4] They are widely distributed across the world's oceans. A 1, 4-linked B-D-mannuronic (M) and a-L-guluronic (G) acid residue makes up alginate's biological structure. Alginate's insoluble form is known as align or alginicacid. Combining alginate with sodium, potassium, or ammonium hydracids creates or transforms it into a soluble salt.[5] An essential characteristic of alginate is its use as an imprint medium for prosthetics and dental impressions.[1] Dental impressions play a crucial role in creating dental models and elucidating oral tissue characteristics.[3] To produce an impression, a properly mixed impression material is ideally placed in a tray and secured by inserting it into the patient's mouth. Utilizing dental plaster or dental stone for the purpose of pouring and creating a cast or model. A favorable impression is generated after the setup, and it is now referred to as a model or a cast.[4]

Commercial dental impressions utilize alginate, which is dispensed as a powdered mixture containing sodium or potassium. Typically, alginate powder comprises approximately 70% diatomaceous earth (filler), 12% sodium/potassium alginate, 12% $CaSO_4$ (cross-linking agent), 4% sodium silicofluoride (pH controller), 2% Na_3PO_4 (retarding agent), and 3% magnesium oxide (pH controller).[3] Alginate is predominantly employed in dentistry for the fabrication of both partial and complete dentures, orthodontic applications, and dental study casts. Alginate is the most widely used impression material globally. Alginates, owing to their characteristics, tend to deform after ten minutes of storage; hence, they are unsuitable for processes such as crowning and bridge preparation after about one to three hours. The reason for this is the dimensional instability of alginate, which tends to contract due to heat variations.[5] The impact of thickness, namely 1mm and 3mm, on the dimensional stability of three dental alginates was examined to replicate clinical scenarios in which impressions differ in thickness. This research aimed to assess the impact of storage duration on three distinct alginate impression materials.

METHODOLOGY

This research examined three distinct kinds of dental alginate materials included in the study: two commercial and one experimentally developed material. The commercial products used in this investigation were Tropicalgin (Zhermach, Italy) and Blueprint Cremix (Dentsply, UK).

The experimental dental alginate is a sodium alginate impression substance created in-house. The composition consists of 14% sodium alginate, 9% calcium sulfate hemihydrate ($CaSO_4$), 3% potassium fluorotitanate (K_2TiF_6), 0.42% tetrasodium pyrophosphate ($Na_4P_2O_7$), 10% magnesium oxide (MgO), and 63.58% diatomaceous earth (filler) (Table 1).

An experimental dental alginate formulation is being investigation alongside two commercially available materials, one of which is used at the Barts and London Dental clinics. The experimental alginate was developed at the Dental Physical Sciences department of Queen Mary University.

The experimental dental alginate used was sodium alginate impression material. A bespoke tray with an attached handle was used for impression preparation, measuring 50 mm in length and 15 mm in breadth, along with a cup that has a diameter of 23 mm and a height of 20 mm, with tiny holes for creating accurate imprints. The disinfecting agent was Perform-ID, containing 45g of pentapotassium bis(peroxymonosulphate) bis(sulphate). The solution was prepared by dissolving 2 measuring scoops of Perform-ID in 2 liters of lukewarm water. The disinfection was conducted by immersion. The elements were meticulously combined by hand in a rubber bowl with a metal spatula. Tap water was used for mixing at around 190°C ±1. The ratio of powder to water was one scoop of powder (9g) with measured water volumes of 17 ml and 24 ml, respectively. The ratios and mixing duration were executed in accordance with the manufacturer's specifications. The setting time for the experimental dental alginate imprint material was 2 minutes and 20 seconds, for Tropicalgin it was 2 minutes and 35 seconds, and for Blueprint Cremix alginate it was 2 minutes and 10 seconds.

All three ingredients, after comprehensive mixing for about 1 minute ± 5 seconds, were poured into a 1 mm thick metal rectangle mold (10 mm x 40 mm) as seen in Figure 1. To guarantee uniformity in size and shape across all samples. A glass slide was positioned on top by applying finger pressure to achieve a smooth surface. The use of 1 mm and 3 mm thick materials was intended to assess any swelling or contraction in each group. In each group, comparable materials and processes were used, with the exception that the thickness of the metal mold was maintained at 3 mm. A total of 36 samples were generated, including 12 samples for each material, categorized into groups of 1 mm and 3 mm thickness. Upon completion of the samples' setting, they were promptly extricated from the mold and weighed. Subsequently, they were stored under the following conditions: after weighing, the samples were exposed to ambient air at room temperature (23°C ±1) and reweighed at intervals of 10, 30 minutes, and 1 hour (10). Any deformed impressions in the mold were omitted from the research. Data analysis was conducted using SPSS version 24.0. The alterations in weight measurement were presented as frequencies and percentages, given their quantitative nature. A P-value of less than 0.05 was deemed statistically significant.

RESULTS

The condition and thickness scores of the materials utilized in this study are presented in Table 2. This includes samples of three dental materials: the commercially prepared Tropical-gin and Blueprint cremix, as well as one experimental formulation, alginate. Each material was categorized into two groups based on the thickness of the metal mold: 1 mm and 3 mm.

The comparison of thickness changes among the three materials Tropicalgin, Blueprint cremix, and an experimentally formulated alginate—stored at thicknesses of 1 mm and 3 mm in air at room temperature is presented in Table 3 and Figure 2. The results indicate that all three materials experienced weight loss over the 10-minute, 30-minute, and 1-hour intervals. The lowest weight loss at each timeline in each group was observed in the experimentally formulated alginate. All three groups exhibited significant changes in thickness; however, group 3 demonstrated the least change, while group 1 showed the greatest change.

Table 1: Manufacturers and Compositions of Experimental Alginate Material Formulation.

Component	Manufacturer	Composition
Mangule®DJX	FMC Biopolymer Ladyburn Works, Girvan, Ayreshire, KA26 9JN, Scotland, UK	Sodium alginate
Potassium fluorotitanate	Rose Chemical Ltd., 73 Englefield Road, London, N1 4HD, UK	
Diatomaceous earth (non- washed)	Sigma-Aldrich Company Ltd., Fancy Road, Poole, Dorset, BH12 4HQ, UK	Cristobalite (72%) and quartz
Crystacast plaster	CFS Partnership, Unit A United Downs Industrial Park, St Day, Redruth, Cornwall, TR16 5HY, UK	Calcium sulphate hemihydrates
Tetrasodium pyrophosphate	Sigma-Aldrich Company Ltd., Fancy Road, Poole, Dorset, BH12 4HQ, UK	
Magnesium oxide	Aldrich Chemical Company Ltd., The Old Brickyard, New Road, Gillingham, Dorset, SP8 4XT, UK	

Table 2: Baseline Information on Material, Thickness, and Condition

Material	Thickness	Condition (Air)	Total samples
Blueprint Cremix (Cluster 1)	1 mm	6	12
	3 mm	6	
Tropicalgin (Cluster 2)	1 mm	6	12
	3 mm	6	
Experimentally formulat- ed (Alginate) (Cluster 3)	1 mm	6	12
	3 mm	6	

Table 3: Shows the frequency of shrinking, or weight loss, in the three materials stored at various times.

	10 min		30 min		1 hour		p-value
	1 mm	3 mm	1 mm	3 mm	1 mm	3 mm	
Blueprint Cremix (Cluster 1)	6.33 % (2.02)	2.76 % (1.62)	10.31% (1.61)	5.55 % (1.31)	18.26% (1.99)	8.34 % (1.32)	<0.01
Tropicalgin (Cluster 2)	4.63% (1.92)	1.76 % (0.84)	8.16 % (1.85)	4.50 % (0.92)	16.71% (1.58)	8.34 % (0.99)	<0.01
Experimentally for- mulated (Alginate) (Cluster III)	3.37 % (0.54)	1.88 % (0.54)	6.86 % (2.33)	4.82 % (0.62)	14.47 (2.14)	8.64 % (0.71)	<0.01

* One-way ANOVA was applied to test for significance in-between the groups

DISCUSSION

The prolonged storage of irreversible hydrocolloid material (alginate) significantly influences its physical, mechanical, and chemical properties, with alginate comprising approximately 85% water. Three processes can impact the accuracy of casts produced from alginates.[6] The syneresis phenomenon refers to the exudation of a liquid film on the surface of a gel.[7] Following the creation of an impression, the clinician may not consistently transfer the material to the dental nurse for disinfection and bagging.[1] This oversight can lead to a reduction in water content due to evaporation and shrinkage, resulting in clinical implications. The calcium-to-sodium ratio is significant in influencing water loss from alginate materials[2]. A high calcium to sodium ratio results in a more rapid loss of water in alginates compared to those with a lower ratio. Despite this, higher filler to alginic polymer ratios and lower molecular weight polymer chains can enhance the dimensional stability of the material.[8] A study quantified water loss from alginates in air through weight change, demonstrating that this loss occurs via a diffusion process. The significant reduction in entropy resulting from the cross-linking reaction leads to decreased water loss from alginate in air during the setting process.[9-11] The theoretical prediction indicates a 1/3 linear shrinkage corresponding to weight loss in the early stages, followed by linear shrinkage in air, as reported in comparison to alginate impression materials and other elastomeric impression materials.[9,13] The study's results indicated that alginate materials exhibited instability after several hours when compared to elastomeric impression materials. The accuracy of 14 impression materials was comparable to that of elastomeric impressions.

When maintained in air at room temperature, the 1mm thick samples exhibited a weight loss that was double that of the 3mm thick samples across three materials: Blueprint Cremix, Tropicalgin, and Experimental formulation. The weight loss for the 1mm thick samples ranged from 14.47% to 16.71%, while the 3mm thick samples experienced approximately 8% weight loss. The thickness is significant in retaining water within alginate materials over extended periods. However, this presents challenges in clinical settings due to the presence of variable thicknesses.

CONCLUSION

The study concluded that both commercial and experimental alginate exhibited dimensional changes at storage intervals of 10 minutes, 30 minutes, and 1 hour. The experimental alginate material exhibited the least weight loss, demonstrating minimal reduction even after one week.

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