Original Article

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Dentistry Section

Environment to Store Alginate at its Best: An In-vitro Study

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ABSTRACT

Introduction: Irreversible hydrocolloid alginate impressions are among the widely used impression materials in dentistry but they suffer from one major drawback, i.e., dimensional change after setting. Because of clinical limitations, impressions are poured to make cast after a time delay which is so long as compared to the recommended period. This can be reduced by storing the impression material in different storage environments.

Aim: To assess the impact of the storage environment on the dimensional accuracy of alginate impression material.

Materials and Methods: In this in-vitro study, 70 samples were made with chromatic alginate impression material according to the manufacturer's guidelines and divided into seven groups (Exposed to atmosphere, Airtight container in the refrigerator, 2% NaCl (Sodium Chloride) solution, Air-tight container, Distilled water, 1% K_2SO_4 (Potassium Sulphate) solution and Mixture of 2% NaCl and 1% K_2SO_4 Solution). Samples were made with stainless steel die fabricated according to ADA specification 18 and dimensions were noted after 24 hours of storage. Distance between the cross lines was calculated using profile projector. ANOVA Test and Tukey Test were applied to compare the mean dimensional change of seven groups and to compare the difference in mean dimensional change between the groups.

Results: Samples kept in a solution of 1% K_2SO_4 and 2% NaCl solution had no significant dimensional change (F-value 2026.0, p-value <0.001), whereas samples stored in open-air resulted in the greatest dimensional change (Group 7 > Group 6 > Group 3 > Group 4 > Group 2 > Group 5 > Group 1).

Conclusion: The impressions which are kept in a combined solution of 1% K_2SO_4 and 2% NaCl have shown the best impact on the dimensional accuracy of alginate impression materials. However, these can also be seen in 1% K_2SO_4 or in 2% NaCl solutions, respectively.

Keywords: Dimensional change, Distilled water, Irreversible hydrocolloid impression materials, Potassium sulphate solution, Sodium chloride solution

INTRODUCTION

Alginate impression materials are the most extensively used dental materials in dentistry [1]. These impression materials were developed in the late 1930s [2]. Because of its admissible accuracy, accessibility, affordable cost, and easy handling, this material is used for many purposes like fabrication of a study model, provisional prosthesis, custom made trays, appliances, and a definitive cast for complete denture fabrication in cases with severe undercuts, removable partial denture and for the maxillofacial prosthesis [1,3].

This impression material is supplied in the form of powder which contains potassium or sodium alginate, calcium sulfate, tri-sodium phosphate, diatomaceous earth, potassium titanium fluoride, zinc oxide, etc. When powder and water are mixed a sol is formed through a reaction between calcium sulfate and sodium or potassium salts of alginic acid. Then alginic salts cross-linked into a flexible matrix by replacement of monovalent sodium and potassium ions with calcium ions [4].

The alginate impression materials suffer from a major disadvantage, i.e. dimensional change after setting of the material which is affected by numerous factors which include the composition of a material, the environment in which impressions are stored, and duration of storage before pouring [1].

Irreversible hydrocolloid impressions materials tend to shrink if they are stored in the air; whereas, if they come in contact with water they swell as a result of imbibitions. Minor changes have also been observed when stored in 100% relative humidity [1].

To achieve maximum accuracy, these impressions should be poured instantly or within 12 minutes. Because of certain limitations, in many cases, impressions are poured at a delayed interval as compared to the normal recommended period. Nowadays, to overcome these, advancements have been done to increase the storage time of hydrocolloid impression materials [1]. Recently, extended storage alginate impression materials have claimed that impressions can be stable if poured within 100 hours [5].

The time and medium in which the material is stored before pouring is a significant factors in the dimensional stability of these materials, thus in the resulting stone casts [6]. Studies on different storage media are limited [4,5].

Thus, this in-vitro study aimed to evaluate the dimensional accuracy of alginate impression material through different storage conditions.

MATERIALS AND METHODS

This in-vitro study was conducted in the Department of Prosthodontics, Crown and Bridge Institute of Dental Sciences Bareilly, Uttar Pradesh, India from October 2016 to April 2019 to evaluate the best environment for storage of alginate impression material in different mediums. The study was undertaken after obtaining Ethical Clearance from the Ethical Committee at SRMS University Bareilly (ME/SRMS/2018-2019/135).

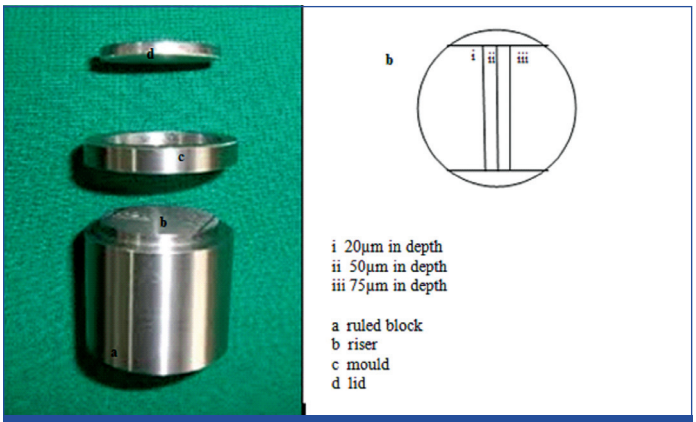
Study Procedure

Chromatic alginate (Vignette, Densply), 2% NaCl solution, 1% K_2SO_4 solution, distilled water were used in the study. The instruments and type of equipments used in the study were stainless steel die according to ADA specification 18, Profile Projector (MEERA METZER), clamp, rubber bowl, spatula, metal plate, stainless steel die, air tight containers. ([Table/Fig-1]: Armamentarium, [Table/Fig-2]: Profile Projector).

A stainless steel die was fabricated according to ADA Specification No. 18 which consisted of ruled block, a mold and a riser. The ruled block had two horizontal and three vertical lines. The vertical lines had a depth of 20 µm, 50 µm and 75 µm, respectively and the

[Table/Fig-1]: Armamentarium.
[Table/Fig-2]: Profile projector. (Images from left to right)

distance between each line was 2.5 mm. The distance between the two horizontal cross lines was 25 mm.The riser was 29.97 mm in diameter and 3 mm in height [5]. ([Table/Fig-3]: Die According to ADA Specification 18).



[Table/Fig-3]: Die According to ADA Specification 18.

Alginate was mixed according to the manufacturer's instructions and placed into the mold. Then the mold was covered with a thin sheet of polyethylene followed by a metal plate. Sufficient force was applied to extrude excess impression material and bring the sheet in contact with the mold. This procedure was performed at a room temperature of 29°C.

To ensure a complete setting, the manufacturer's instructions were followed and the mold and test block were separated. After setting, the impression was pressed out of the mold using the riser. A numeric coding system was used to identify the sample. Seventy samples were made and they were divided into seven groups; group 1 to group 7. The descriptions of groups are as follow:

Group 1- Exposed to the atmosphere

Group 2- Air tight container in refrigerator

Group 3- Solution of NaCl at 2% concentration [4]

Group 4- Air-tight container

Group 5- Distilled water

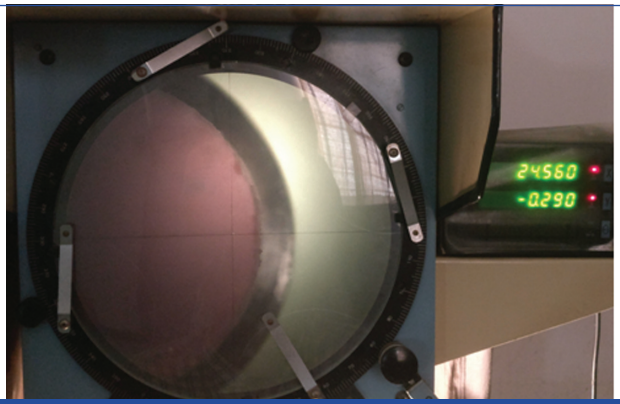
Group 6- Solution of K_2SO_4 at 1% concentration [4]

Group 7- Solution of 2% NaCl and 1% K_2SO_4

Distance between the cross lines, on the ruled metal block, was measured to the nearest 0.005 mm and recorded as reading A ([Table/Fig-4]: Alginate sample for dimensional accuracy, [Table/Fig-5]: Alginate samples for dimensional accuracy before and after 24 hours). Then again this distance was measured after 24 hours of storage in different environments. These measurements were recorded for 10 samples as B-1 to B-10 in each group to same all the group, respectively. The dimension of lines was measured at the nearest 0.005 mm by using a Profile Projector (MEERA METZER) and the readings were recorded accordingly ([Table/Fig-6]: Measurements of distance between crosslines).

[Table/Fig-4]: Alginate sample for dimensional accuracy.

[Table/Fig-5]: Alginate samples for dimensional accuracy before and after 24 hours.



[Table/Fig-6]: Measurements of distance between crosslines.

All the obtained observations were collected and dimensional change was calculated as follows:

Dimensional change%=(A-B)/A×100 [5]

STATISTICAL ANALYSIS

The results were subjected to statistical analysis in SPSS software (Windows version 17.0) to evaluate the dimensional accuracy of alginate in different storage mediums. ANOVA test and Tukey test were applied to compare the dimensional accuracy of alginate in each group.

RESULTS

The dimensional change of the seven groups is summarised in [Table/Fig-7]. The mean dimensional change of Group 7 was the least followed by Group 6, Group 3, Group 4, Group 2, Group 5, and Group 1 the highest. Comparing the mean dimensional change

of seven groups, ANOVA showed significantly different dimensional changes among the groups (F=2026.0, p<0.001) [Table/Fig-8].

Further, comparing the difference in mean dimensional change between the groups, the Tukey test showed significantly (p<0.001) different and lower dimensional change of Group 2 (90.3%), Group 3 (91.6%), Group 4 (90.4%), Group 5 (87.3%), Group 6 (92.3%) and Group 7 (94.3%) as compared to Group 1 [Table/Fig-9].

Groups	N	Min	Max	Mean	SD	SE	Median
Group 1	10	4.94	5.38	5.13	0.16	0.05	5.15
Group 2	10	0.38	0.63	0.50	0.11	0.03	0.50
Group 3	10	0.24	0.58	0.43	0.11	0.04	0.45
Group 4	10	0.35	0.72	0.49	0.11	0.04	0.48
Group 5	10	0.52	0.90	0.65	0.13	0.04	0.61
Group 6	10	0.32	0.57	0.40	0.09	0.03	0.38
Group 7	10	0.07	0.51	0.29	0.15	0.05	0.32

[Table/Fig-7]: Summary statistics of dimensional change (mm) of seven groups.
Min: minimum; Max: Maximum; SD: Standard deviation; SE: Standard error

Source of Variation (SV)	Sum of Square (SS)	Degrees of freedom (df)	Mean Square (MS)	F-value	p-value
Between groups	187.50	6	31.25	2026.0	<0.001
Residual	0.97	63	0.02		
Total	188.50	69	31.27		

[Table/Fig-8]: Comparison of mean dimensional change of seven groups by ANOVA.
F-value: ANOVA F-value

Comparison	Mean Diff.	Mean diff. (%)	q-value	p-value	95% CI of diff.
Group 1 vs. Group 2	4.63	90.3	117.90	<0.001*	4.46 to 4.80
Group 1 vs. Group 3	4.70	91.6	119.60	<0.001*	4.53 to 4.87
Group 1 vs. Group 4	4.64	90.4	118.10	<0.001*	4.47 to 4.81
Group 1 vs. Group 5	4.48	87.3	114.00	<0.001*	4.31 to 4.65
Group 1 vs. Group 6	4.73	92.3	120.50	<0.001*	4.56 to 4.90
Group 1 vs. Group 7	4.84	94.3	123.10	<0.001*	4.67 to 5.00
Group 2 vs. Group 3	0.07	13.4	1.69	0.71	-0.10 to 0.24
Group 2 vs. Group 4	0.01	1.3	0.17	0.079	-0.16 to 0.18
Group 2 vs. Group 5	-0.15	23.6	3.91	0.082	-0.32 to 0.02
Group 2 vs. Group 6	0.10	20.2	2.56	0.72	-0.07 to 0.27
Group 2 vs. Group 7	0.20	41.0	5.19	<0.01*	0.03 to 0.37
Group 3 vs. Group 4	-0.06	12.2	1.53	0.68	-0.23 to 0.11
Group 3 vs. Group 5	-0.22	33.8	5.60	<0.01*	-0.39 to -0.05
Group 3 vs. Group 6	0.03	7.9	0.87	0.078	-0.14 to 0.20
Group 3 vs. Group 7	0.14	31.9	3.50	0.095	-0.03 to 0.31
Group 4 vs. Group 5	-0.16	24.6	4.07	0.488	-0.33 to 0.01
Group 4 vs. Group 6	0.09	19.2	2.39	0.91	-0.08 to 0.26
Group 4 vs. Group 7	0.20	40.3	5.03	<0.05*	0.03 to 0.37
Group 5 vs. Group 6	0.25	39.0	6.47	<0.001*	0.08 to 0.42
Group 5 vs. Group 7	0.36	55.0	9.10	<0.001*	0.19 to 0.53
Group 6 vs. Group 7	0.10	26.1	2.64	0.098	-0.07 to 0.27

[Table/Fig-9]: Comparison of difference in mean dimensional change between groups by Tukey test.
Diff: Difference; q value: Tukey q value; CI: Confidence interval; p-values marked in red are significant

Further, it was also found significantly (p<0.001) different and lower in both Group 6 (39.0%) and Group 7 (55.0%) as compared to Group 5. Further, it also lowered significantly (p<0.05 or p<0.01) in Group 7 as compared to both Group 2 (41.0%) and Group 4 (40.3%). Moreover, it also lowered significantly (p<0.01) in Group 3 (33.8%) as compared to Group 5. However, it is not differed (p>0.05) between other groups i.e., found to be statistically the same.

DISCUSSION

Based on the current study, the result states that the combination of 2% NaCl and 1% K_2SO_4 was the best medium for the storage of alginate impression material. The samples stored in NaCl solution, K_2SO_4 solution, or in air tight containers were also showing minimal dimensional changes whereas the samples stored in open atmosphere showed the highest dimensional changes.

The impact of storage of impression material in K_2SO_4 and NaCl solutions can be explained by Hofmeister or lyotropic series in which the ions of metallic salts were arranged in order of their decreasing ability to precipitate lyophilic substances from colloidal dispersion (anion order: SO_4^{-2} >$C_2H_3O_2^-$ > Cl^->NO_3^- >ClO_3^->I^- >CNS; cation order: Mg^{2+} >Ca^{2+} >Sr^{2+} >Ba^{2+}>Li^+ >Na+ >K^+). As the coagulation power/extent of coagulation of gel is high, volume will decrease and thus shrinkage takes place. The surface stabilization for a limited period of time can be achieved by immersion in dilute aqueous solution of 2% NaCl and 1% of K_2SO_4 or a combination of both [4]. Alginate contains approximately 70% water due to which this set alginate is subject to syneresis. As a result, the network of interlinked molecules constricts, and water is expelled from the interstitial spaces between the alginate chains. This results in shrinkage even though the material is also still hygroscopic and capable of absorbing water via imbibition, which results in the expansion of the impression [7]. There is no universal standard for clinically acceptable changes of these impression materials. The inaccuracy up to a range of 78 µm and 50 µm, respectively are acceptable and also investigated the accuracy between the dies and the crown [8].

The effect of different fixing solutions on the irreversible hydrocolloid impression materials has been studied about composition and concentration by Skinner EW et al., [9]. They concluded that the materials are dimensionally stable if they are stored in an environment which is of 100 percent relative humidity [9].

In distilled water the impression samples initially expands, because of the absorption of water to reach equilibrium. But after few hours because of the negative effect (decrease in weight) heavier components from the gel are substituted with lighter constituents (H^+ ions) of water [4]. In despite of its several advantages, dimensional changes of alginate is one of the major concerns [10]. If an impervious film of some nature can be formed over the surface of the impression, no molecular exchange can take place between the atmosphere and the impression material, with no resulting imbibitions, syneresis and dimensional change [9]. Findings of studies on different storage medias are compared in [Table/Fig-10] [4,5,11-13].

S. No.	Author's name and year	Place of study	Number of samples	Storage environments used	Conclusion
1.	Walker MP et al., 2010 [5]	Missouri	90 impressions were made with 3 different alginate materials (30 each)	Three different storage times were used 30 minutes, 48 hours, 100 hours, respectively	Extended pour alginate impression materials shows minimal dimensional change after 100 hours of storage as compared to conventional alginates.
2.	Mosharraf R et al., 2011 [13]	Iran	15 impressions were made with three different alginate materials (5 each)	Five different storage times were used 0,24,28,72 and 120 hours, respectively	The extended pour irreversible hydrocolloid impression materials did not exhibit any significant dimensional difference after 120 hours.

3.	Jayaprakash K et al., 2014 [4]	Mangalore, Karnataka	42 impressions were made for 7 different groups	Seven different storage environments were used relative humidity, refrigerator, refrigeration at closed plastic sachet, humid chamber, distilled water, NaCl at different conc., K_2SO_4 at different conc.	During transport to distant laboratories, the impressions can be stored in lower concentration of NaCl and K_2SO_4 solution.
4.	Aalaei S et al., 2017 [11]	Tehran	60 impressions were taken of an upper jaw typodont, including 10 impressions for each storage period	Three different storage periods were used 12 minutes, 24 hours and 120 hours respectively	The irreversible hydrocolloid materials are dimensionally stable for 24 hours at consistent humidity and temperature.
5.	Gomase PV et al., 2019 [12]	Wardha, Maharashtra	Four alginate impressions were made with ivory tooth mounted in dental stone	A total of Four storage conditions were used- 0.02% NaCl solution and 0.05% K_2SO_4 solution at different atmospheric conditions	The impression can be stored in 0.02% NaCl at 8±2 °C solutions preferentially followed by 0.05% of K_2SO_4 at 8±2 °C solutions, in a sealed polythene sachet for about 24 hours
6.	Present study	Bareilly, UP	70 samples were made and divided into seven different groups	Seven different storage conditions were used exposed to the atmosphere, air-tight container in refrigerator, solution of NaCl at 2% conc, airtight container, distilled water, solution of K_2SO_4 at 2% conc, solution of 2% NaCl and 1% K_2SO_4	The impressions which are kept in a combined solution of 1% K_2SO_4 and 2% NaCl has shown the best impact on the dimensional accuracy of alginate impression materials.

[Table/Fig-10]: Similar studies from the literature [4,5,11-13].

Limitation(s)

The limitation of this study is that the flat surface of alginate was used to record the prescribed, disregarding the possibility of dimensional changes in three dimensions. Moreover, the tested alginate samples do not represent clinically relevant forms as in real impressions in clinical practice.

CONCLUSION(S)

Based on the results of study, it is concluded that keeping the impressions in the solution of 1% K_2SO_4 and 2% NaCl is the best method for maintaining the dimensional accuracy of alginate. It can also be stored in 1% K_2SO_4, in 2% NaCl, solutions for about 24 hours, facilitating the shifting to distant laboratories from the clinics. However, further research can be done to study the dimensional changes in clinical situation.

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