Effect of composition of alginate impression material on "recovery from deformation"

Saniour S.H.S[1], Abd El-Ghaffar M.A.[2], Fath El-Bab I.I[1] and Saba D.A.[*1].

[1]Dental Biomaterials Department, Faculty of Oral and Dental Medicine, Cairo University, Cairo, Egypt
[2]Chemistry and Technology of Polymers Department, National Research Center , Dokki, Giza, Egypt
[*]daliasaba@hotmail.com

Abstract: The aim of the present study was to investigate the effect of various alginate impression materials compositions on the recovery from deformation property. Experimentally alginate mixtures; Alg I, Alg II, Alg III, Alg IV, and Alg V and Alg VI, were prepared showing various composition regarding the concentration of the sodium alginate, calcium sulphate dihydrate, containing traces of calcium sulphate hemihydrates or calcium sulphate dihydrate of high purity were used. Five specimens for each experimentally prepared alginate mixture were made. The "recovery from deformation" of the specimens was evaluated according to the ANSI/ADA specification no.18 for dental alginate impression material. The obtained values of the recovery from deformation for all the materials tested were subjected to One-way Analysis of Variance (ANOVA) for comparison between groups. The results revealed that Alg I showed the lowest statistically significant mean recovery from deformation (89.8%). There was no statistically significant difference between Alg II (93%), Alg III (93.9%), Alg IV (94.3%), Alg V (94.3%) and Alg VI, which showed the highest statistically significant mean recovery from deformation (95.3%). It was concluded that the concentration of the sodium alginate chemical did play a major role in the preparation of the experimental alginate mixtures. Experimentally prepared alginates containing calcium sulphate dihydrate rather than those containing mixtures of hemihydrate and dihydrate, showed higher "recovery from deformation".
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Key words: Alginate impression material, recovery from deformation, sodium alginate, calcium sulphate dihydrate

1. Introduction

Over the years, wide varieties of impression materials and their associated techniques have been developed, all striving to achieve the optimum desirable characteristics. At the present time, hydrocolloids and synthetic elastomeric polymers are among the most commonly used materials to make impressions for the various areas of the dental arch [(1-4)].

Alginate impression material is considered one of the groups often referred to as "elastic impression materials". It was firstly used in 1940s when agar impression material became scarce. Alginate impression material is usually available in the markets in the form of powder containing soluble alginate salt, calcium sulfate, and fillers as the primary components [(5- 8)].

In dental alginate impression materials, increasing or decreasing the percentage of the alginate salt was found to modify, almost proportionally, the properties of the impression. For instance, high proportions of the alginate salt were reported to improve the resilience of the impression material. Moreover, hardness readings indicated that the increase in the alginate content might lead to the formation of a progressively firmer and harder gel [(9)].

On the other hand, the source of calcium ions is usually calcium sulphate in the dihydrate ($CaSO_4.2H_2O$) or the hemihydrate ($CaSO_4.1/2H_2O$) form. Calcium sulphate is usually present in an amount ranging from about 10 to 20% by weight in the alginate impression powder [(9-12)].

After mixing with water, gelation of the impression material occurs where a 3-dimensional network of alginate chains cross-linked with the calcium ions is formed [(13-15)].

Nowadays, alginate impression materials rank among the most frequently used impression materials in dentistry. They are used for the production of study cast where absolute stability is not critical. Moreover, its use becomes a universal routine in dental profession especially for the production of master casts needed for the fabrication of mouth guards, splints, bleaching trays etc., [(16-18)].

The accuracy of an impression material is usually related to its mechanical properties of recovery from deformation, strain in compression, compressive and tear strengths [(19)].

The "Recovery from deformation" represents the ability of the alginate material to recover after it has been deformed during removal from the mouth. Therefore, the greater the recovery from deformation, the more accurate the impression material will be [(20)].

Therefore, the aim of this study is to investigate the effect of various alginate impression materials compositions on the recovery from deformation property.

2. Material and Methods:

The experimentally prepared alginate mixtures were designated; Alg I, Alg II, Alg III, Alg IV, and Alg V and Alg VI, as shown in table (1).

The various compositional modifications were performed in the following sequence:

1. In the chemical composition of the first experimentally prepared alginate mixture (Alg I), calcium sulphate dihydrate containing traces of hemihydrate was used.
2. In Alg II, another commercially available type of calcium sulphate dihydrate of higher purity was tried using the same percentages of all the ingredients as was used in Alg I.
3. In Alg III, the percentage of sodium alginate was raised from 12% to 14% on the expense of the diatomaceous earth filler while, the first type of the calcium sulphate dihydrate was used. The percentages of the other ingredients were not changed.
4. In Alg IV, the raised percentage of the sodium alginate (14%) was used in conjugation with the second type of the calcium sulphate dihydrate.
5. In Alg V, further increase in the percentage of the sodium alginate from 14% to 16% (on the expense of the diatomaceous earth filler) was tried in conjugation with the first type of the calcium sulphate dihydrate.
6. Finally, in Alg VI, the final raised percentage of sodium alginate (16%) was tried with the second type of the calcium sulphate dihydrate without changing the percentages of the other ingredients.

Table (4): The compositional modifications tried in an attempt to raise the percentage of the "recovery from deformation".

Components	Alg I (For comparison)	Alg II	Alg III	Alg IV	Alg V	Alg VI
Sodium alginate	12	12	14	14	16	16
Calcium sulphate dihydrate	14*	14**	14*	14**	14*	14**
Tetra-sodium pyrophosphate	2.5	2.5	2.5	2.5	2.5	2.5
Zinc oxide	2	2	2	2	2	2
Potassium flourotitanate	1	1	1	1	1	1
Diatomaceous earth	65.5	65.5	63.5	63.5	61.5	61.5
Polyethylene glycol	3	3	3	3	3	3

* Calcium sulphate dihydrate containing traces of hemihydrates ** Calcium sulphate dihydrate of high purity

The "recovery from deformation" of the experimentally prepared alginate mixtures were evaluated according to American National Standard/American Dental Association (ANSI/ADA) specification no.18 for dental alginate impression material. In addition, the testing procedures followed, were compatible with the International Standard Organization ISO 1563:1990 for dental alginate impression material, which was found to be technically identical to the ANSI/ADA specification no.18 [21,22].

Distilled water was used for mixing the commercial materials as well as the experimentally prepared alginate mixture. The temperature of the water was maintained throughout the study at 23±1°C, as stated by the ADA specification.

For the experimentally prepared alginate mixture, the water/powder ratio was standardized to 16 ml water/ 7 g powder [23].

For proportioning, the powder was weighed using a sensitive balance accurate to 0.001g. The distilled water was dispensed using a plastic syringe.

The powder was added to the distilled water in a rubber bowl and immediately hand speculated using a stainless steel spatula. The time of the initial contact of the powder with the water was considered the start of the mixing procedure.

Preparation of test specimens:

Specimens for the **recovery from deformation** were prepared as follows [20, 21]:

Five specimens for each experimentally prepared alginate mixture were made. The specimens were made by placing a plastic fixation ring (20.5 mm inside diameter, 19 mm high) on a flat glass plate and filling the ring slightly more than half-full with the mixed alginate material. A copper split-metal mould (12.5 mm inside diameter, 20.5 mm outside diameter and 20 mm high), Figures (1, 2), was placed immediately inside the fixation ring and pushed into the material until the split-metal mould touched the glass plate and the alginate material was extruded above the top of the split mould. A glass plate was then pressed on the mould to remove the excess alginate material and to form a flat smooth upper surface of the specimen. At the stated initial setting time, each specimen was separated from the split mould assembly.

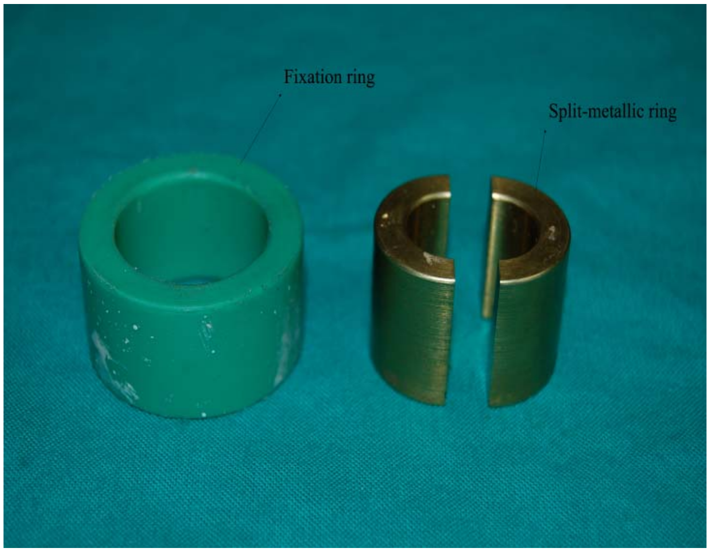

Figure (1): The fixation ring and the split-metallic ring used for the preparation of the specimens for measuring the "recovery from deformation|".

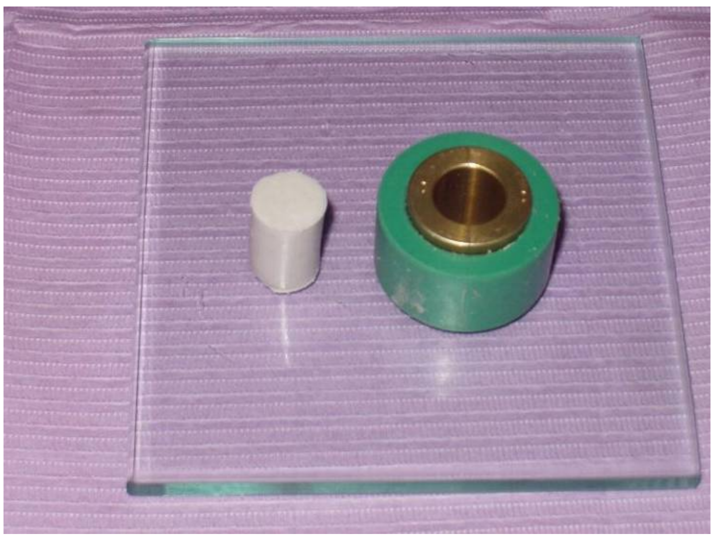

Figure (2): The alginate specimen and the assembled (fixation and split rings) mould.

Procedures:

The test was conducted in accordance with the following time schedule where *t* was the initial setting time [20-22,24]:

(a) t + 45 seconds—the spindle of the dial indicator (IHG, Germany), Figure (3), was lowered so that it came into contact with the plate on the specimen.

(b) t +55 seconds—the dial indicator was read, the value was recorded as the initial reading (a) in mm.

(c) t + 60 seconds—the specimen was then transferred to a tensometer (Monseinto Tensometer, United kingdom) Figure (4), and deformed to a height of 16 mm (20% strain) within four seconds. The deformation was maintained for 5 seconds, and then released.

(d) t + 90 seconds—the deformed specimen was then transferred to the dial indicator and the spindle of the dial indicator was lowered so that it came into contact with the plate on the specimen.

(e) t + 100 seconds— the dial indicator was read, and the value was recorded as reading (b) in mm.

The recovery from deformation was

calculated as a percentage using the following formula, indicated by the ADA specification no. 18:

$$100 \times [1- (a-b/20)]$$

Where 20 was the length of the mold, in millimeters.

The average values of the recovery from the deformation of five specimens, for each impression material tested, were recorded and statistically analyzed.

To meet the ANSI/ADA requirements, the recovery from deformation should be at least 95%.

Figure (3): The dial indicator used for measuring the recovery from deformation.

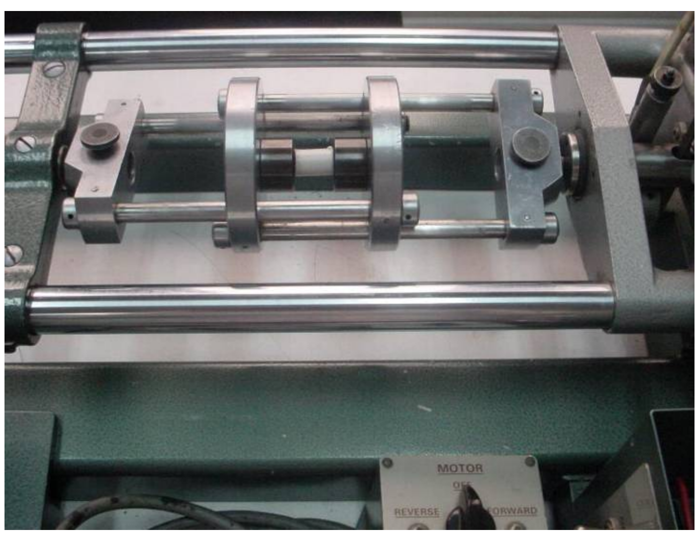

Figure (4): The tensometer used for deforming the specimens of the “recovery from deformation” test.

Statistical Analysis

The obtained values of the recovery from deformation for all the materials tested were subjected to One-way Analysis of Variance (ANOVA) for comparison between groups.

The data were given as mean values, standard deviations and calculated P-value. The significance level was set at $P \leq 0.05$. Tukey's post-hoc test was used for pair-wise comparison between the means when ANOVA test was found significant. Statistical analysis was performed with SPSS 16.0) (SPSS, Inc., Chicago, IL, USA, Statistical Package for Scientific Studies) for Windows.

3. Results:

As shown in table (2), it can be noticed that Alg I showed the lowest statistically significant mean recovery from deformation (89.8%). There was no statistically significant difference between Alg II (93%), Alg III (93.9%), Alg IV (94.3%), Alg V (94.3%) and Alg VI, which showed the highest statistically significant mean recovery from deformation (95.3%).

Table (2): Means (±SD) values of the trials to raise the recovery from deformation (in %) for the experimentally prepared alginates

Alg I	Alg II	Alg III	Alg IV	Alg V	Alg VI	***P*-value**
89.8±2.5 [b]	93±0.7 [a]	93.9±0.5 [a]	94.3±0.3 [a]	94.3±0.5 [a]	95.3±0.2 [a]	**<0.001***

Values are mean ± SD, *: Significant at $P \leq 0.05$, Means with different letters are statistically significantly different according to Tukey's test.

4. Discussion:

The ANSI/ADA specification no.18 requires a recovery from deformation of at least 95% [21]. Alg I did not meet the ANSI/ADA requirements as it showed the lowest statistically significant mean recovery from deformation (89.8%). This lowest value for the recovery from deformation of the Alg I might be related to the presence of calcium sulphate hemihydate ($CaSO_4.1/2H_2O$) in its composition. This was found to be in agreement with *Buchan and Peggie (1965)* [9] who stated that mixtures containing dihydrate gave gels with lower permanent deformation than corresponding mixtures with the hemihydrate.

In addition, the lowest value of the recovery of deformation of Alg I might have been attributed to the low concentration of the sodium alginate (12%) in comparison to the rest of the experimentally prepared alginates (16%). This was in agreement with *Weakest Link Theory* [25], which stated that as the alginate concentration is raised (and the filler content is reduced); the actual strain on each chain will be lowered when the material is deformed. Consequently, a smaller fraction of the network chains will be ruptured and the permanent deformation will decrease. Therefore, the followed trails to raise the values of the recovery from deformation were done by changing the commercial type of the calcium sulphate dihydrate and by increasing the percentage of the sodium alginate until the "Alg VI" did pass the ANSI/ADA requirement for the recovery from deformation (95.3%), table (2).

Conclusions;

1. Under the conditions of the present study, the following conclusions were evident:
2. The concentration of the sodium alginate chemical did play a major role in the preparation of the experimental alginate mixtures.
3. Experimentally prepared alginates containing calcium sulphate dihydrate rather than those containing mixtures of hemihydrate and dihydrate, showed higher "recovery from deformation".

Corresponding author
Saba D.A
Dental Biomaterials Department, Faculty of Oral and Dental Medicine, Cairo University, Cairo, Egypt
daliasaba@hotmail.com

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