ORIGINAL ARTICLE

A COMPARISON OF ALGINATE IMPRESSION PRODUCTS IN TERMS OF STIFFNESS BASED ON YOUNG'S MODULUS

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ABSTRACT

The purpose of this study was to evaluate the stiffness of five commercially available different alginate impression materials namely Cavex CA37®, Cavex Color Change®, Tulip®, Cavex Cream Alginate® and TOL® so that one can deduce which material is the most suitable for taking accurate impressions of deep sulci and undercuts. The study was divided in to five groups (one for each product) with thirty samples each, which were tested for hardness using shore A durometer. This was done at three time points, i.e. ends of working and setting times and the point at which a constant value of hardness was achieved, so there were three subgroups for each material, containing ten samples each. The modulus of elasticity at these time points was calculated using the Gent relationship for each material. Data were analyzed using SPSS version 22, by the repeat measure ANOVA test. p value less than 0.05 was considered significant. Curves were plotted using Microsoft Excel for each material for comparison The results showed that the elastic moduli increased at all times in the following order; Cavex Cream Alginate®> Tulip®> Cavex Color Change®> TOL ®> Cavex CA37® and the rate of increase was greater at the end of working time, and later decreased. It was deduced that the most appropriate alginate product for deep sulci and undercuts was Cavex CA37®. However, studies including detail reproduction studies, dimensional stability studies and disinfection protocols etc are warranted to accurately specify the suitability of each product for clinical applications.

Key Words: *Alginate impressions, stiffness, young's modulus.*

INTRODUCTION

Clinicians need to be aware of the setting characteristics of each of the myriad of different alginate impression materials available today in the market, so that they are able to choose appropriately for different clinical applications. The availability of modern alginate impression materials under various product names and claims has made it difficult for clinicians to choose the appropriate one for clinical applications.[1] The introduction of desirable properties such as being dust-free, fast setting, having improved pour time and improved dimensional stability have upgraded the quality of alginate as an impression material. However, this also calls for a need to study in detail the mechanical properties and setting characteristics of these modified materials.[2,3] One needs to have adequate knowledge of the setting behaviors of these new branded alginate materials before one can apply them clinically.

Alginate impression materials are required to have a certain degree of viscosity to flow to all areas of oral cavity.[4] One important property of impression material is the stiffness of the set material.[5] This stiffness gives a measure of the force required to remove the impression from the undercut areas in the mouth.[6] Elastic and less stiff impression materials are easier to remove from the mouth.[2]

Finger et al have divided this force in to the following three components: 1) the under pressure created during removal of the impression material from the undercut; 2) the friction created as the deformed impression material moves along the surfaces; and 3) the deformation required to remove the impression from the undercut region. This deformation force dominates all three components of the force in most cases and may be considered proportional to the elastic modulus, given that the deformation is only elastic.[7,8]

Stiffness also affects the likelihood of model fractures during their construction in the lab sue to the effect on the ease of removal. A less stiff material

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would be easier to remove, causing less risk for model fracture.[6]

There seems to be very little published data available on the relative force required to remove the alginate impression material from the mouth, particularly in relation with Young's Modulus.[9] Furthermore, although the viscoelastic response of alginate has been studied on various levels, a comparison of the various modified alginate formulations has yet to be done in this regard.[10,11] The purpose of the following study was firstly to compare five new commercial products of alginate in terms of stiffness based on Young's modulus, and secondly to outline a reasonably accurate prediction model for these modern alginate impression materials in terms of ease of impression removal from undercut areas and replication of deep sulci and undercuts accurately.

METHODOLOGY

Five types of commercially available Alginate materials were used in this study as listed in Table 1. Thirty alginate samples from each alginate group were prepared and divided into three subgroups (consisting of 10 samples each, n=10) namely A (after working time), B (after setting time) and C (after a constant value of elastic modulus was achieved). The working and setting times given by the manufacturer are given in Table 2.

A disc shaped mould (dimensions H =4mm, W= 6mm,), shown in Fig 1, was used to prepare disc shaped identical samples as per manufacturer's instructions according to ISO 1563 and ISO 21563 for alginate impression materials. The mix was allowed to set inside the circulating water bath (Thermo Scientific, 2864) in artificial saliva at 98.6°F (37°C) to simulate the setting environment of the oral cavity.

After sample preparation of three subgroups the hardness value for each sample was measured using shore A durometer (NOVATEST- D190310216). This is illustrated in figure 2. The correlations between durometer and Young's Modulus put forth by A. N. Gent was used

$$E = 0.0981(56 + 7.62336S)\ 0.137505(254 - 2.54S)$$

Where E = Young's modulus in MPa and S = ASTM D2240 Type A durometer hardness.

This equation was used to calculate the modulus of elasticity at three point times. Statistical analysis was performed using SPSS version 22, using the repeat measure ANOVA test.

RESULTS

Table 3 enlists the Shore A hardness values and the corresponding elastic moduli as a function of time. The trends shown by the elastic moduli of different materials shown by Fig 3 have been assigned different

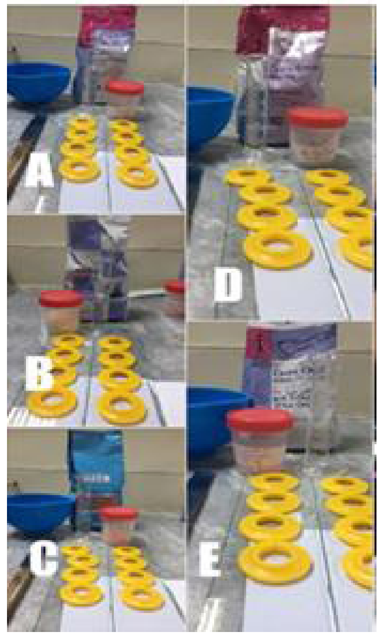

Fig 1: Split moulds used in the study and a rubber bowl and plaster spatula used to manipulate the alginate products including A, Cavex Color Change®; B, Tulip®; C, TOL ®; D, Cavex Cream Alginate®; and E, Cavex CA37®

Fig 2: Hardness Testing: A, Standardization blocks of the durometer; B, testing of the alginate samples by the durometer

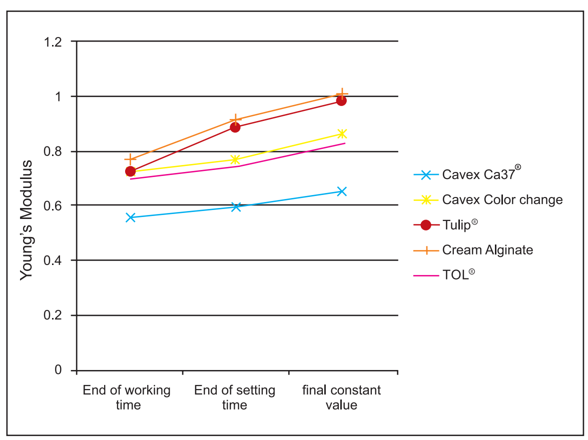

Fig 3: Trends showed by the elastic moduli of the different materials. Significant difference was found between the groups ($p<0.05$)

TABLE 1: ALGINATE IMPRESSION MATERIALS TESTED IN THIS STUDY

S. No.	Group Number	Commercial Name	Claimed Specification	Lot No.
1	I	Cavex CA37®	Normal Set Dust free	150518
2	II	Cavex Color Change®	Fast Set Dust Free	160220
3	III	Tulip®	Dust Free Elastic	150873
4	IV	Cavex Cream Alginate®	Normal Setting	160509
5	V	TOL®	Dust free Mint flavored German ingredients Fast set	1505181

TABLE 2: WORKING AND SETTING TIMES OF THE ALGINATE PRODUCTS GIVEN BY THE MANUFACTURER

Alginate Product	Working Time (min)	Setting Time (min)
Cavex CA37®	2	3.3
Cavex Color Change®	1.3	2.3
Tulip®	1.3	3.3
Cavex Cream Alginate®	2	3.3
TOL®	0.3	1

TABLE 3: SHORE A HARDNESS VALUES WITH CORRESPONDING YOUNG'S MODULI ACHIEVED AT DIFFERENT TIME POINTS. SIGNIFICANT DIFFERENCE WAS FOUND BETWEEN THE GROUPS (P<0.05)

Materials	At the end of Working Time			At the end of Setting Time			Final Constant		
	Shore A hardness (mean)	Young's Modulus (MPa)	Standard Deviation	Shore A hardness	Young's Modulus (MPa)	Standard Deviation	Shore A hardness at (x) min	Young's Modulus (MPa)	Standard Deviation
Cavex CA37®	1	0.56	±0.12	2.5	0.59	±0.04	5 (13)	0.65	±0.01
Cavex Color Change®	8	0.72	±0.02	10	0.77	±0.05	14 (10)	0.86	±0.02
Tulip®	8	0.72	±0.05	15	0.89	±0.06	19 (10)	0.98	±0.02
Cavex Cream Alginate®	10	0.77	±0.07	16	0.91	±0.07	20 (7)	1	±0.03
TOL ®	7	0.7	±0.03	9	0.75	±0.05	12.5 (10)	0.83	±0.03

colors. The trends show that the elastic moduli increase with time for each material. After the setting time, the rate of this increase decreases for all except Cavex Color Change® and TOL®. The statistical analysis shows that significant difference was found between the groups ($p<0.05$).

According to the results of this study, the elastic moduli of the materials were found to be in the following order: Cavex Cream Alginate®> Tulip®> Cavex Color Change®> TOL®> Cavex CA37®. Although Tulip® and Cavex Color Change both have similar initial elastic moduli, Tulip® got much stiffer rapidly over time. Cavex CA37® was the least stiff material.

DISCUSSION

The setting characteristics and mechanical properties of set and unset impression materials allow the user to gauge their workability for clinical applications. Amongst other aspects, properties like stiffness and elastic moduli give an idea of the force that needs to be applied to remove the impression from the oral cavity. In previous studies, rheological and viscoelastic properties have mostly been studied for the elastomeric impression materials.[10-13] However, alginate is also known to exhibit these properties.

The viscoelastic properties of impression materials allow a certain degree of deformation during removal of impression. Set alginates are inherently elastic and much less rigid than elastomers.[14] It has been proved by previous studies that unset alginate possess Bingham behavior i.e it behaves as a viscoplastic material that behaves as a rigid body at low stresses but flows as a viscous fluid at high stress.[15] After setting alginate should behave as a viscoelastic material so that it will deform slightly during the removal from the undercut area and then due to its elastic properties re-attain its original configuration.

The changes in the elastic modulus shown by alginate during setting are well established.[16] However, the comparison of the commercial products in terms of stiffness has been done for the first time in the present study. This comparison has shown that all five alginate products exhibited increasing elastic moduli, and therefore stiffness. The rate of this increase is higher during the working time, but decreases after that. This reflects that most of the reaction, quick in nature, has already taken place by the end of the working time[17] and after that the minimal amount of remaining reaction ingredients continue to react giving a further, slower increase in hardness.

Recommendations drawn from previous studies include that the alginate impression should be removed with a firm quick snap. Rocking and twisting is discouraged during or before alginate impression removal to minimize distortion.[18] Since this study elucidates that Cavex CA37® is the least stiff material at all times, it can be deduced that an impression made with Cavex CA37® will require the least force during removal. This impression material will deform according to requirement during removal from an undercut, and reform accordingly later. It can also be said that the distortion created by any rocking and twisting will also be the least in this product.

The highest elastic modulus has been showed by Cavex Cream Alginate® at all times, elucidating that this material is the stiffest at all time points. The stiffness of this material dictates that it will recover less after removal from undercut areas compared with other tested products. This means that distortion while material is setting will be less owing to its stiffness, but the set material may distort more in comparison with other materials during removal due to less elastic recovery.

The reason of the varying hardness of these commercial products with essentially similar basic composition may lie in the ingredients of the different products. It has been shown by Nallamuthu et al that magnesium oxide containing alginate products are harder.[9] Another study has shown that if the sodium alginate contents are increased in the alginate, hardness is increased, but this may result in increased permanent deformation.[19]

Although this study suggests that an impression taken using Cavex CA37® impression alginate will require the least force during removal without deformation of the impression, this does not mean that this material will give the most accurate impression. There are many other factors that may affect the overall accuracy of the replication of the oral structures by an impression. Adequate removal time for alginates is also important.[20]

Another important contributing factor is the time elapsed between mixing and pouring. Studies in which various commercial products were compared show that the impression should be poured as quickly as possible to achieve maximum recovery from deformation and minimum stress relaxation.[20-22] According to the present study, Cavex Color Change® was a relatively stiffer material. Rodrigues et al have shown that Cavex ColorChange® showed 95% recovery from deformation until third day[23], which was better than other tested products. This implies that a measure of stiffness may not be the only factor affecting the accuracy and dimensional stability of an impression material. This also means that the validity of an alginate product's choice depends on the particular clinical application. For example, Cavex CA37®, predicted by the present results to suffer the least overall deformation, may be preferred in circumstances in which deep sulci and undercuts are to be recorded.

Overall accuracy of replication also depends upon dimensional stability of the particular product. The effect of processes such as syneresis and imbibition produced in a particular commercial alginate product is an important parameter that should be studied to assess its overall accuracy.

Overall, this study shows that the elasticity of set modern alginates is good. This study also suggests that if one is faced with deep sulci and undercuts in the clinical scenario, the choice of alginate impression materials from amongst the modern products tested herein is Cavex CA 37®. However, it must be kept in mind that the stiffness or the elasticity at set is not the only property that defines the overall accurate tissue replication by an alginate product. Studies including dimensional accuracy, syneresis and imbibition and detail reproduction must be performed for each of these materials to dictate the final choice for each clinical application.

CONCLUSION

Based on the methods and conditions employed in the present study it is concluded that an impression taken using Cavex CA37® alginate impression material would require the least force for the removal of the impression from undercut areas and will deform less, while Cavex Cream Alginate® will have the opposite effect. It is recommended that in circumstances where one is confronted with deep sulci and undercut areas, Cavex CA37® should be considered the material of choice from amongst the tested impression materials.

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