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Dimensional Stability of Newer Alginate Impression Materials over Seven Days

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Abstract - *The aim of this study was to determine the dimensional stability of the so called '5 day stable' alginates. Ten specimens each of three alginate materials were prepared using a standardised impression technique and a typodont model. Travelling microscope measurements were recorded for six distances at 24 hour intervals. SEM and EDX analysis was undertaken. Changes in dimension over time and differences between materials were tested using analysis of variance. 95% confidence intervals were calculated for the percentage change for comparison with a target of 1.5% based on the ISO Standard. Statistically significant dimensional changes were observed in some measured distances for all materials, but only six out of fifty four distances measured at 1, 5 and 7 days in three materials showed 95% confidence intervals that included the 1.5% ISO standard. There were no statistically significant differences in the proportional change between the three materials. The three materials showed similar appearance under SEM and similar composition by EDX analysis. It is concluded that all materials demonstrated good dimensional stability over the recommended maximum of 5 days.*

KEY WORDS: alginate impression material, dimensional stability, prolonged storage.

INTRODUCTION

The use of alginate dental impression material for the production of study casts, orthodontic appliances, removable prostheses, mouth guards, etc., is a universally practiced routine in the dental profession[1]. The material is easy to use, well tolerated by patients and a cost-effective method of producing dental impressions and casts. Unfortunately, as the material is a hydrocolloid it dehydrates, and distorts and so dental cast must ideally be made soon after the impression has been removed from the mouth[1,2].

Despite it being widely accepted that alginate is not stable on storage, the literature pertaining to the effect of storage times on dimensional stability of the set alginates is limited. Most of these studies reported were carried out for a maximum storage period of 24 hours and concluded that alginates did not remain stable under ideal storage conditions[3] even for as little as three hours[4]. The majority of studies use cast models to measure dimensional stability and not actual impressions and so variables were included such as the dimensional stability of the model material and how it was manipulated [3,4,5].

Alginate impressions are three-dimensional semi-permeable gels when set; they exhibit the two distinct processes of syneresis and imbibition. In the set material the gel structure results from the coordination of lengths of the polysaccharide chains in junction zones to form a three-dimensional network. This results in a setting shrinkage and after the initial stage when cross-linking nodes have been established, further coordination results in a shortening of the uncoordinated sections as the lengths of the junction zones grow [6]. The consequence is that free water is gradually extruded on the surface, which is termed syneresis. This process cannot be ameliorated by any change in the handling of the set impression. These materials are also prone to water absorption, termed imbibition [6]. Both syneresis and imbibition have the potential for causing dimensional changes and account for the poor dimensional stability of alginate impression materials.

Studies by previous workers on effects of storage conditions on alginate materials have limited relevance today as many of the materials studied are no longer available and different protocols with no reference to ISO[7,8], ADA[9] or British Standard specifications [10] were used [11,12,13,14,15]. In a recent study however, Hydrogum 5, which is marketed as being "5 day stable", was shown to be dimensionally stable for that period of time against a contrast group of conventional alginate impression materials [16].

More recently, much interest has focused on the effects of disinfection on dimensional stability [17,18,19]. Conclusions are difficult to draw as the results were contradictory, and both the methods of disinfection and experimental protocols differed. There is no universally accepted best practice for achieving disinfection with alginates and a recent extensive review of the literature on disinfecting regimes for impression materials demonstrated that evidence was still lacking. This included the clinical significance of any changes observed as well as surface detail reproduction. However, overall, the review concluded that chemical disinfection produced dimensional changes that are not likely to affect clinical outcomes [20].

The aim of this study was to investigate the dimensional stability of two newer alginate dental impression materi-

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als, which are claimed to be dimensionally stable for five days, using a third impression material as a contrast group. To reduce the number of variables, impressions were measured rather than casts, and the impressions were not subject to any disinfection. The composition of the alginate materials was investigated using energy dispersive x ray analysis (EDX).

MATERIALS AND METHODS

Materials

Three alginate impression materials from different manufacturers were included in the study. Aroma Fine DF was chosen as the contrast group, the other two were chosen as their manufacturers' claim that the impressions remain dimensionally stable for up to five days (Table 1).

Preparation of the Master Model

A plastic typodont model (Fig. 1) was used as a master model with cingulum rests prepared on 13 and 23 and mesio-occlusal rests on 16 and 27. Reference markers were cut in the prepared rest seats to a diameter and depth of 1.5mm using a dental milling machine. Reference markers on teeth 27, 23, 13 and 16 were labelled A, B, C and D respectively.

The typodont model was then mounted on a plaster-less articulator. The mounting was fixed to give a consistent and repeatable relation during impression recording. The placement of the trays was standardised by allowing the tray to contact the lower member of the articulator. The articulator was adjusted to give approximately 3mm space between the tray and the teeth.

The alginate impression materials were mixed according to the manufacturers' recommended instructions using a clean rubber bowl mounted on an electrical alginate mixer, and a clean flexible plastic spatula. Deionised water was used at room temperature (21°C ± 2C°), following the manufacturers' instructions for water-powder ratio, the alginate powder was weighed on an Electronic Balance. Mixing and setting times were followed as per the manufacturers' instructions and timed using a stop watch (Table 2).

The materials were spatulated for the stipulated mixing times to obtain a smooth homogenous mix and the metal stock trays were loaded with an excess amount of material. Some material was applied to the reference teeth so as to ensure that the impression did not incorporate any air blows in the areas to be used for measurements. The loaded tray was carefully positioned on the typodont model, with moderate pressure to allow the material to flow through the perforations. The upper member of the articulator, which held the model and the impression tray, was then lowered until the point where the tray contacted the base of the articulator (Fig. 2).

The impression was separated from the model with a single quick movement (snap) to minimise the amount of permanent deformation during removal. The impression was then carefully examined for errors and defects and special attention was given to the reproductions of the reference markers. The impressions were rinsed in running tap water for 10 seconds and excess water was shaken off. The impressions were immediately transferred to a sealed plastic container which maintained an environment of 100% relative humidity. This was monitored every 24 hours using a humidity meter. The impressions were stored in these conditions throughout the course of the study and removed daily only for measurement. The containers were left standing in ambient laboratory conditions 20°C ± 3°C so as to replicate a normal UK laboratory environment. A total of 30 impressions were recorded, 10 for each material with recording of impressions and measurement undertaken in two separate batches.

Table 1. *Selected alginate impression materials*

Trade name & Manufacturer
Aroma Fine DF, GC, Tokyo, Japan
Hydrogum 5, Zhermack, Rovigo, Italy
Xantalgin Crono, Heraeus Kulzer, Germany

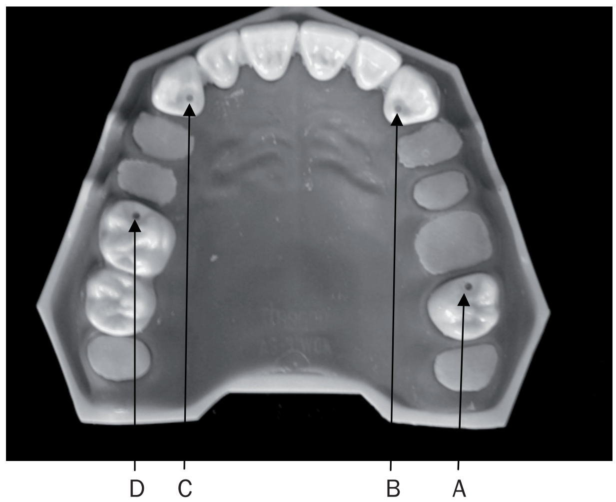


Figure 1. *Typodont master model with reference points A, B, C and D*

Table 2. *Manufacturers' recommendations*

Alginate	*Water/Powder ratio*	*Mixing Time (seconds)*	*Setting Time (seconds)*
Aroma Fine	2.38	30	180
Hydrogum 5	2.14	30	110
Xantalgin Crono	2.22	40	135

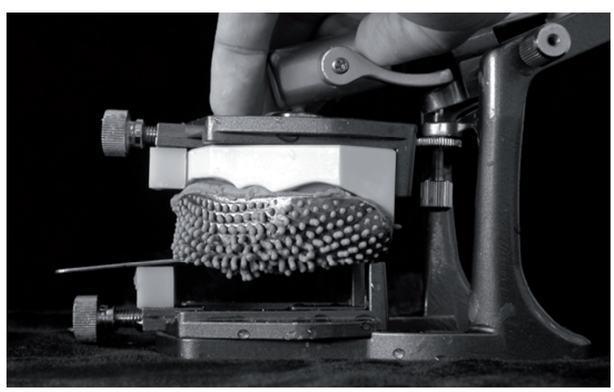


Figure 2. *Final position of the impression on the model*

To standardise measurement, each impression was positioned on the lower member of the articulator in a similar fashion as for impression recording. This entire assembly was then carefully positioned under a travelling microscope, using x12 magnification with an accuracy of ±5µm. The referencing markers were positioned in such a fashion that the cross-hair of the microscope were made to align as tangents to their circumference, keeping the markers in the second quadrant for every measurement. Three repeated measurements were undertaken for each co-ordinate and the procedure was repeated for every impression every day starting from Day 0 up to Day 7.

Scanning electron microscope (SEM) and Energy dispersive X-ray (EDX) analysis

Specimens of each material (dry alginate powder) were prepared by mounting on aluminium stubs using carbon putty and sputter coated with carbon. The specimens were then subjected to SEM and EDX analysis. Data was analysed using the embedded X-ray microanalysis software.

STATISTICAL ANALYSIS

Data was analysed using STATA 10 software. Factorial analysis of variance (ANOVA) was used to test for differences in the proportional change between materials and over time. Subsequently, differences between measurements at baseline and those at 1, 5 and 7 days were analysed using repeated measures analysis of variance for each material and distance separately. Post-ANOVA contrasts were carried out using a Bonferroni test where appropriate. The proportional difference between baseline measurements and those at 1, 5 and 7 days was also calculated and expressed as a percentage. ANOVA was used to test for differences in the proportional change between materials. Statistical significance was inferred at $p<0.05$. Confidence intervals for the proportional difference from baseline were calculated to provide an indication of the range within which the real proportional change might be expected in the parent population that this sample represents and for comparison with the 1.5% ISO standard.

RESULTS

Dimensional changes

Table 3 shows the mean dimension of each distance measured at baseline. Tables 4-6 show the percentage change from baseline for each of the three materials together with the 95% confidence intervals for the change. The majority of distances showed a relatively small change in dimension at 1, 5 and 7 days for all materials. There were no statistically significant differences in proportional change between the materials. Statistically significant changes were observed at 5 days and 7 days in distance BC and CD for Aroma Fine ($p<0.05$). Hydrogum 5 only showed significant changes at 7 days in distances AD and BC ($p<0.05$). Xantalgin Crono showed a number of significant changes: Distances AC, AD, BC and CD at 5 days and AD, CD and BD at 7 days ($p<0.05$). None of the mean changes was greater than 1.5%.

The 95% confidence intervals, indicating the range within which the percentage change would be expected in the parent population, included the 1.5% ISO standard in six out of the fifty four measurements. Confidence intervals for Aroma Fine included 1.5% at 7 days for distances AB and CD. Distance CD confidence intervals included the 1.5% standard at 1, 5 and 7 days for Hydrogum 5. Confidence intervals for distance CD also included the ISO standard at 7 days for Xantalgin Crono.

SEM and EDX Analysis

Figs. 3-8 show the SEM and subsequent EDX analysis undertaken on the entire field width and also on selected particles of each material. The SEM photomicrographs of the powder of each material showed similarities between the materials. The organic content occupied the majority of the volume and particle size was similar across the three materials. The area EDX again showed that the materials were very similar with the elements Oxygen, Silica, Calcium, Potassium, Sulphur, Aluminum and Magnesium all present. EDX anlysis of the particles although representative of each material showed a very uneven distribution of elements in invdual particles. Zinc was found only in Aroma Fine (Figs. 3 and 4, Particle 2). Titanium was found in high proportions in Hydrogum 5 and Xantalgin Crono and Fluorine was present in Hydrogum 5.

DISCUSSION

Alginate impression materials have long been believed to deform after impression recording on storage, by either of two processes syneresis and imbibition [11,14]. In this study variables were reduced by mechanical mixing to ensure regular consistency although it has been reported that there is no major difference in the physical properties of alginates using either hand or mechanical mixing [21]. The powder-water ratio was controlled by accurate weighing as opposed to the use of the volume measures provided by the manufacturers, as it was observed in the pilot studies that the powder-water ratio varied significantly when the manufacturers' measures were used. An adhesive or polyester fibre-mat material[22] was not used on the trays to aid retention as it was considered difficult to control the uniformity of its application hence resulting in loss of standardisation. The metal trays used provided retention due to the distribution of perforations.

Measurements were carried out after an hour to allow time for elastic recoil of the impressions in the regions engaging minor undercuts. A travelling microscope was used for the measurements of the impressions in line with ISO ADA specifications for Alginate impression materials [7, 9].

The results indicate that, apart from the distance AD which showed an apparent increase in dimension, most of the other measured dimensions for all the materials at all time points showed a decrease (Tables 4-6). There were few statistically significant differences between the measurements at baseline and Days 1, 5 and 7 for Aroma Fine and Hydrogum 5. Xantalgin Crono showed a number of statistically significant changes. However, all such changes were small, and no mean dimensional change was greater than 1.5%. Although this percentage is the standard set by the ISO for elastomeric dental impression materials, it was adopted as the target in the present study due to the lack of any set standard for alginate. The 95% confidence

Table 3. *Mean (standard deviation) dimensions of the six distances at baseline*

DISTANCE					
AB	*AC*	*AD*	*BC*	*CD*	*BD*
27.23 (0.12)	47.91 (0.29)	48.42 (0.12)	29.67 (0.09)	18.44 (0.48)	40.29 (0.12)

Table 4. *Mean (standard deviation) and 95% confidence intervals for the percentage change in dimensions from baseline to 1, 5 and 7 days for Aroma fine*

DAY	*DISTANCE*					
	AB	*AC*	*AD*	*BC*	*CD*	*BD*
1	-0.046 (0.479) 0.297, -0.389	-0.137 (0.143) -0.035, -0.239	0.152 (0.436) 0.464, -0.160	-0.122 (0.167) -0.002, -0.241	0.066 (0.582) 0.483, -0.350	0.198 (0.419) 0.497, -0.101
5	-0.564 (1.034) 0.176, -1.304	-0.254 (0.260) -0.068, -0.440	+0.134 (0.178) 0.261, +0.006	-0.271* (0.203) -0.125, -0.416	-0.831* (0.797) -0.261, -1.401	-0.165 (0.267) 0.026, -0.356
7	-1.318 (2.004) 0.116, -2.752	-0.522 (0.784) 0.038, -1.083	0.345 (0.867) 0.966, -0.274	-0.430* (0.269) -0.238, -0.623	-0.875* (0.904) -0.229, -1.521	-0.064 (0.742) 0.467, -0.594

* Statistically significant change from baseline
Shading indicates 95% confidence intervals that include the 1.5% ISO standard

Table 5. *Mean (standard deviation) and 95% confidence intervals for the percentage change in dimensions from baseline to 1, 5 and 7 days for Hydrogum 5*

DAY	*DISTANCE*					
	AB	*AC*	*AD*	*BC*	*CD*	*BD*
1	0.138 (0.725) 0.657 to -0.380	-0.062 (0.431) 0.413 to -1.026	0.180 (0.229) 0.344 to 0.016	-0.065(0.432) 0.115 to -0.369	-0.039 (0.312) 1.376 to -4.288	0.086 (0.355) 0.341 to -0.168
5	-0.499 (1.274) 0.413 to -1.410	-0.317 (0.612) 0.174 to -1.258	0.253 (0.275) 0.450 to+0.057	-0.311 (0.608) -0.046 to-0.523	-0.205 (0.465) 0.891 to 4.847	-0.027(0.267) 0.164 to-0.219
7	-0.264 (0.612) 0.173 to-0.702	-0.412 (1.109) 0.252 to-1.194	0.303*(0.232) 0.470 to+0.138	-0.436*(1.104) -0.281 to-0.698	-0.262 (0.967) 1.100 to-4.768	-0.129(0.253) 0.052 to -0.310

* Statistically significant change from baseline
Shading indicates 95% confidence intervals that include the 1.5% ISO standard

Table 6. *Mean (standard deviation) and 95% confidence intervals for the percentage change in dimensions from baseline to 1, 5 and 7 days for Xantalgin Crono*

DAY	*DISTANCE*					
	AB	*AC*	*AD*	*BC*	*CD*	*BD*
1	-0.116(0.235) 0.052 to -0.310	-0.083 (0.224) 0.078 to -0.243	0.008 (0.077) 0.064 to -0.046	-0.118 (0.225) 0.043 to -0.280	-0.541(0.595) -0.115 to -0.967	-0.166 (0.198) -0.024 to -0.307
5	-0.398 (0.508) -0.034 to -0.761	-0.273* (0.160) -0.158 to -0.386	0.152 (0.121) 0.238 to 0.066	-0.339*(0.312) -0.115 to -0.562	-0.837* (0.644) -0.377 to -1.298	-0.159 (0.189) -0.024 to -0.294
7	-0.512 (0.592) -0.089 to -0.935	-0.192 (0.416) 0.105 to -0.490	0.164* (0.095) 0.232 to 0.096	-0.121 (0.910) 0.530 to -0.773	-1.448*(1.319) -0.504 to -2.392	-0.267* (0.246) -0.091 to -0.442

* Statistically significant change from baseline
Shading indicates 95% confidence intervals that include the 1.5% ISO standard

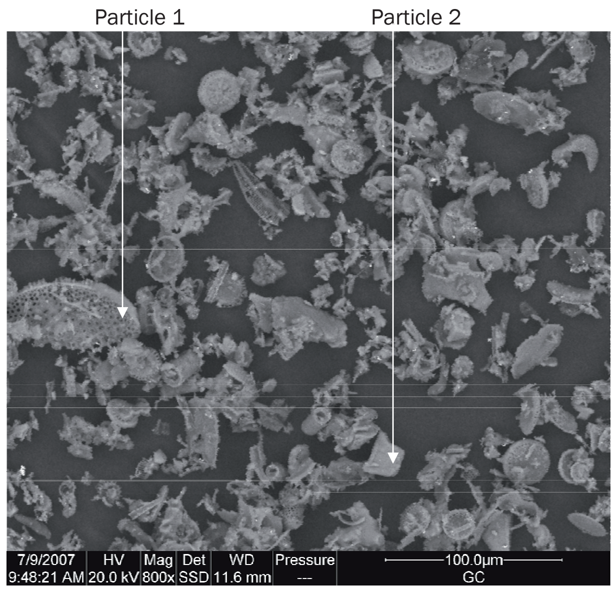
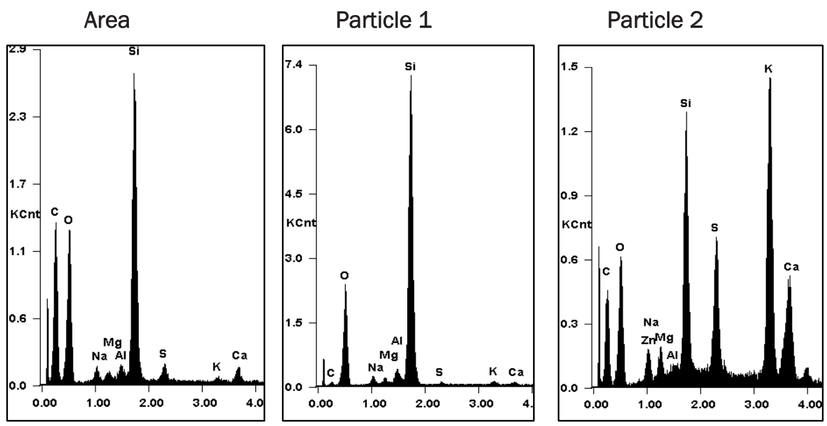


Figure 3. *SEM Photomicrograph for Aroma Fine*



KV: 20.00 TILT: 0.00 TAKE-OFF: 36.51 AMPT: 12.8 DETECTOR TYPE: SUTW-SAPPHIRE RESOLUTION: 135.51

Figure 4. *EDX Analysis of Figure 3*
The area EDX shows presence of significant amounts of Silica and Oxygen. Other elements present were Sodium, Magnesium, Aluminum, Sulphur, Potassium, and Calcium. Particle 1 shows a similar profile with less Oxygen. Particle 2 shows high levels of Potassium, Silica, Calcium, and Sulphur and the presence of Zinc.

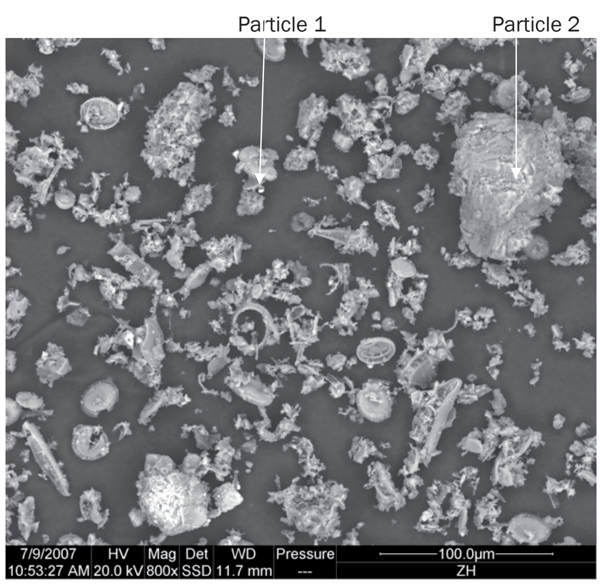


Figure 5: *SEM Photomicrograph for Hydrogum 5*

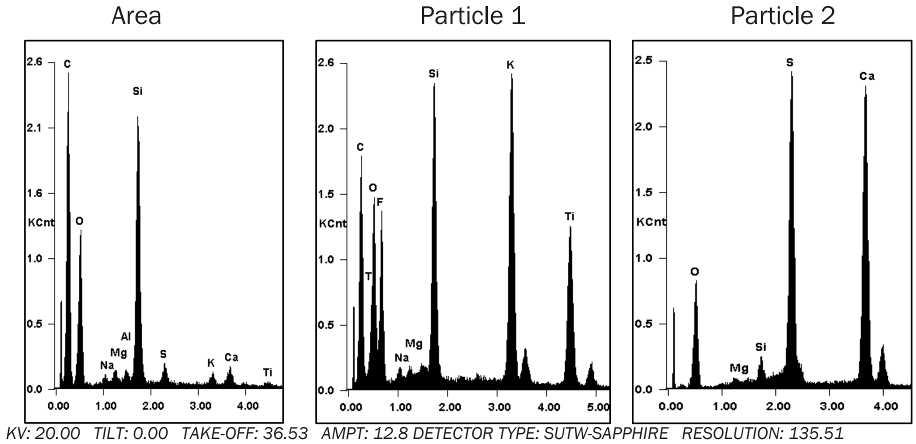


Figure 6: *EDX Analysis of Figure. 5*
The area EDX shows significant amounts of Silica and Oxygen. Other elements present were, Sodium, Magnesium, Aluminum, Sulphur, Potassium, Calcium and Titanium. Particle 1 shows high levels of Silica, Potassium, Titanium and Fluorine while Particle 2 shows high levels of Calcium, Sulphur and Oxygen.

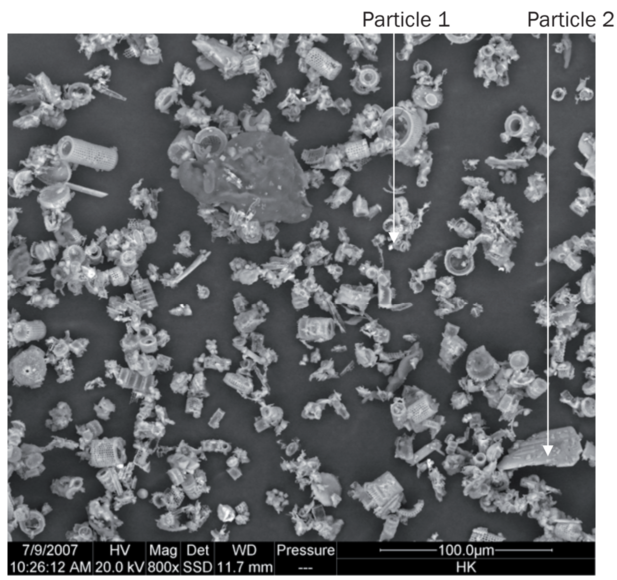


Figure 7. *SEM Photomicrograph for Xantalgin Crono*

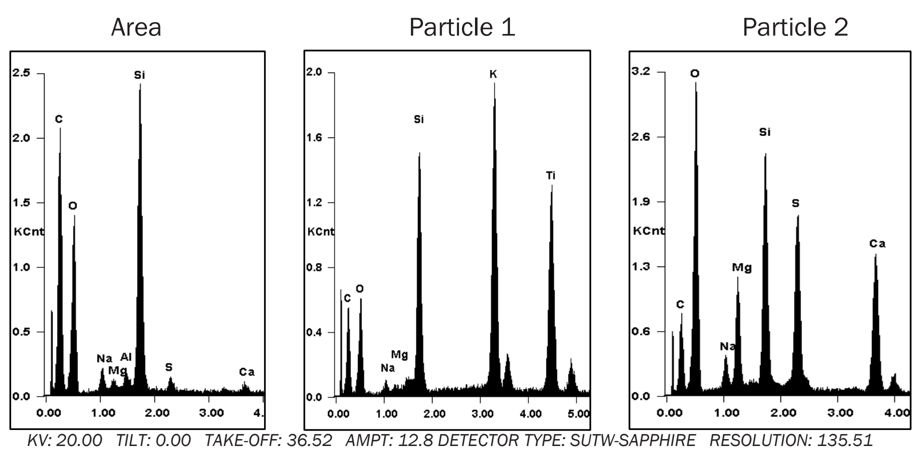


Figure 8. *EDX Analysis of Figure 7*
The area EDX shows presence of significant amounts of Silica and Oxygen. Other elements present were Sodium, Magnesium Aluminum, Sulphur and Calcium. Particle 1 shows high levels of Silica, Potassium and Titanium while Particle 2 shows high levels of Oxygen, Silica, Sulphur, Calcium and Magnesium.

intervals for the proportional changes confirmed that there were few changes that could be expected to be greater than this standard. Of the six changes where the confidence intervals exceeded this standard, five were for the smallest distance, measured between teeth 13 and 16 (CD). This decrease in dimension was 153µ for Aroma Fine, 395µ for Hydrogum 5 and 154µ for Xantalgin Crono at 5 days, and similar at 7 days.

The present results are not entirely in agreement with previous findings. Chen *et al*[23] showed that two alginate materials were not stable over a 24 hour period, whilst Eriksson *et al*[3] stated that alginate did not show dimensional stability over a period of 95 hours. However, methodological differences between these investigations and the present study make comparisons difficult. Sedda et al[16] investigated the accuracy of casts made from five alginates, including Hydrogum 5 and found that this material was the only one that was stable after 5 days.

The SEM investigation of the powder of each material showed similarities between the materials. The organic content occupied the majority of the volume. Results of EDX analysis showed that the three materials used in the study included the following basic elements of Oxygen, Silica, Calcium, Potassium, Sulphur, Aluminum and Magnesium. Zinc was found in only in Aroma fine, Titanium found in high proportions in Hydrogum 5 and Xantalgin Crono and Fluorine just in Hydrogum 5. It may be that these elements have been added by manufactures to try to improve the set stability.

Buchan and Peggie[24] studied the role of different ingredients in alginate impression materials and like others[25] they tried to relate dimensional stability as a factor of water gain or loss. They studied the effects of proportions of sodium alginate, trisodium phosphate, calcium phosphate, inorganic fillers and hydrogen ion concentration (pH) on the physical properties such as rebound elasticity, permanent deformation and hardness of the materials. The conclusions of the study were that in the first few hours an increased amount of sodium alginate had little effect on the amount of water lost by syneresis. After 48 and 72 hours the gelled compound had a higher degree of dimensional stability but was of little clinical importance. Impressions when placed in 100% humidity continued to absorb water when the proportion of trisodium phosphate was increased, but the effects on dimensional stability were not stated. That presence of inorganic filling materials reduced the shrinkage when syneresis occurred and gave improved dimensional stability to the impression. Furthermore as silicofluoride concentration increased, the setting time decreased and the gel becomes firmer and harder thus reducing permanent deformation.

To reduce the variables of this *in vitro* study, the impressions were not disinfected as there is no consensus as to the optimal method to avoid deterioration of set alginate and so the clinical relevance of the dimensional stability has not been demonstrated. In clinical practice the impression would have to be disinfected. The study measured the impressions up to seven days which is two days longer than the manufacturers of “5 day stable” alginate recommend. At Day 5 few statistically significant changes were observed and only Hydrogum 5 showed a potential change above 1.5% with the smallest distance. All other distances in all materials were dimensionally stable at 5 days. Even impressions not cast immediately and sent to a remote laboratory through the post would normally be cast within two to three days.

Fenlon *et al.* [26] defined intimate contact using a tolerance level of 50µm or less as a measure of good fit of metal frameworks. Jamani [5] stated that a discrepancy of 150µm was acceptable in fabrication of the cast metal framework and his statement was later re-iterated by Rudd *et al.*[27]. It has been reported that a discrepancy of 0.18 mm on a cast metal framework was large enough to admit a dental probe thus probably increasing the initiation of food accumulation and possible disease progression[28]. In the present study only one material, Hydrogum 5, showed a dimensional change greater than 160µm in one of the six distances measured at 5 days. It is extremely difficult to justify the relationship of the quoted tolerance levels for dimensional accuracy of the alginates as all the figures are a consequence of all the procedures necessary to construct a framework. The changes occurring in the set alginate are not uniform, as observed in this study, as it expanded in certain dimensions and contracted in another. This phenomenon can be influenced by variables such as application of adhesive on the tray, the volume of material between the tray and the tissue surface, depth and position of the undercuts, water-powder ratio and consistency of the mixture and storage conditions. Small variations can result in deleterious consequences in the clinical outcome. This gives rise to a situation in which the discrepancies need to be controlled and kept to a minimum rather than attempting to eliminate them altogether which can be recognized as good clinical practice, by for example using accurate water-powder ratio, correct choice of stock tray and optimal storage.

CONCLUSIONS

Within the limitations of this *in vitro* study it was concluded that the three alginate impression materials, two of which are marketed as “5 day stable” materials, demonstrated good dimensional stability over that period, and acceptable stability over a period of seven days when stored in 100% relative humidity.

ACKNOWLEDGEMENTS

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MANUFACTURES’ DETAILS

- Typodont model (Frasaco, Tettnang, Germany)
- Dental milling machine (Galloni, Milan, Italy)
- Plaster-less articulator (Yamaura, Tokyo, Japan).
- Impression trays (Perforated trays No.1 Coe trays GC America Inc Alsipi IL USA)
- Alginate mixer (Zhermack, Italy)
- Electronic Balance (OertlingTP30, Orpington, UK)
- Travelling microscope (Graticules Ltd, Kent, UK)

- SEM (Hitachi High Technologies Corp. Berkshire UK)
- EDX analysis (Quanta 200F Field Emission Electron Microscope, FEI, Cambridge, UK)
- Microanalysis software (EDAX Genesis Spectrum Version 3.6, EDAX Inc., Mahwah, NJ, USA)
- STATA 8 software (STATA Corp., TX, USA).

ADDRESS FOR CORRESPONDENCE

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