The compatibility of locally available alginate materials with gypsum materials

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Dentistry in the field of Prosthodontics .

Johannesburg, 2013

DECLARATION

I, Alfred Kudakwashe Taruvingira, declare that this research report is my own work. It is being submitted for the degree of Master of Dentistry of the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other University.

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31 October 2013

ABSTRACT

Purpose: To assess and measure the compatibility of irreversible hydrocolloids (alginates) readily available in South Africa with available gypsum products by testing the quality reproducibility of lines on a standard die.

Method: Under controlled laboratory conditions six brands of alginate impression material were tested against six types of gypsum products using the EN 21563:1991 (ISO 1563:1990) recommended protocol. Photomicrographs of the resultant gypsum surfaces were taken and a scoring method similar to that described by Owen (1986b) was used by previously calibrated independent examiners in order to evaluate the acceptable alginate/gypsum combinations.

Results: There was an unexpected variability in the rater scores, and considerable variability in the quality of the casts from the various possible alginate/gypsum combinations. Statistical analysis allowed for the use of combination mean scores taking into account all the scores of all the raters, but discrimination was limited to those combinations with the best scores. The best possible score was 3 and the worst 12. In light of the inter-rater variability the combinations with scores of 4 or less were considered to be the recommended combination for clinical application. No alginate proved to be universally compatible with all the gypsum products tested and no gypsum product was universally compatible with all alginates.

Conclusion: This study has highlighted the fact that not all alginates are compatible with all gypsum products, and that it is possible to find appropriate combinations for the

clinical requirements of a dental cast. However, the fact that there were nine combinations which scored in the very worst category means that manufacturers of alginates should recommend specific gypsum products with which they are compatible and which were used to obtain their ISO rating, and clinicians should be more aware of the need for compatibility.

ACKNOWLEDGEMENTS:

I thank the Dental Warehouse; H & P Dental; Wright Millners; Dentsply; and Megadent for providing the dental materials. Secondly, I thank Mr H. Moyane for his dependable technical assistance. Lastly, I thank my supervisor, Prof CP Owen for his guidance and relentless support.

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CHAPTER 1. INTRODUCTION

1.1 Background

Dental alginate (an irreversible hydrocolloid material) is said to be one of the most commonly used dental materials (Jarvis & Earnshaw, 1980; Nandini et al, 2008; Walker et al, 2010). It is also a material that has been used over a long period of time both in prosthodontic work as well as orthodontics (Walker et al, 2010). Gypsum casts are constructed from impressions from a variety of materials for a variety of uses. Whatever the use, it is important for the surfaces of the gypsum casts to reproduce adequate detail captured by the impression for the subsequent procedures to be a success (Jarvis & Earnshaw, 1980). Incompatibility between certain alginates and gypsum products has been reported (Jarvis & Earnshaw, 1981). Such incompatibility results in gypsum casts that have surface roughness and other discrepancies such as unclear margins. Owen (1986a; 1986b) recommended some alginate/gypsum combinations that were compatible and produced good surface detail. However since then, there have been very little, if any, follow up studies that were conducted to test the compatibility of the materials used currently, or indeed if the same compatibilities still exist.

1.2 Literature Review

The U.S Navy is said to have first used alginate for dental impressions during World War II (Parvin, 2003). Thereafter, it spread to the rest of the dental profession. It is crucial for an impression material to capture accurate intra-oral detail and be able to transfer it to a gypsum cast (Jarvis & Earnshaw, 1980). Lack of accurate transference of surface detail has been noted from the time alginates were first introduced. This has been attributed to incompatibility at the alginate/gypsum interface (Jarvis & Earnshaw, 1980; Owen, 1986a). Recommendations from these studies have led to improvements in the compatibility of these materials. Alteration of the alginates' chemistry has largely contributed to enhanced compatibility as this led to smoother surfaces and reduced fluid loss from the alginate (Jarvis and Earnshaw, 1981). Dust-free alginates were introduced in 1985 and showed superior ability in reproducing detail and in producing a good surface quality of the cast (Owen, 1986a). This may be due to the incorporation of silicone particles which reduced the dust cloud common in previous alginates. Since that time most alginates purport to be dust free, but there may still be issues of compatibility in the chemical interaction between alginate and gypsum. It is unlikely that the particle size of the gypsum contributes to this, as the average particle size of dental gypsum products has been shown to be less than 50μm (Williams et al 1984).

The properties of all alginate impression materials should conform to the International Standard ISO 1563 which requires the alginate and gypsum combinations to reproduce lines on a test block (BSI 1991). In his follow up study, Owen (1986b) suggested the need to modify the ISO standards for alginates, and recommended that the ISO demands be made more realistic and measuring tools be more sensitive to provide more discriminating evaluations. This was because a wide variety of surface detail reproduction was found and the ISO standard concentrates more on the reproducibility of the lines on a standard die.

Since 1986 there have been no other studies published dealing purely with the compatibility of alginate and gypsum, but a wide range of alginates is now available from different companies. It has been the clinical experience at the Wits Oral Health Centre that some of these materials have produced an inferior surface quality of the resultant casts, and hence the need to study these products objectively.

CHAPTER 2. AIMS AND OBJECTIVES

Aim.

The aim of this study was to compare the compatibility of locally available irreversible hydrocolloids (alginates) with available gypsum products by assessing the detail reproduction on gypsum casts.

Objectives.

1. To use a variety of dental alginates available in South Africa to record impressions of the ISO-approved standard die.
2. To assess the surface detail reproduction on gypsum casts of different alginate/gypsum combinations by using independent observers to rate the casts.
3. To establish the most compatible alginate/gypsum combinations.

CHAPTER 3. METHOD AND MATERIALS

3.1 The ISO standard die

The IS0 standard die was purchased from Ravenfield Designs Ltd (U.K), and comprises a ruled test block and ring moulds for alginate and gypsum. The British Standards Institution has published the European Standard EN 21563:1991 (BSI 1991). This European Standard has been taken over by CEN/TC 55 (“Dental products") from the work of ISO/TC 106 ("Dentistry") of the International Organization for Standardization (ISO) and is according to the ISO 1563:1990 specifications.

Figure 1 shows the surface of the die with the lines of different thicknesses, a representing the 50µm line a, the 20µm line b and the 75µm line c.

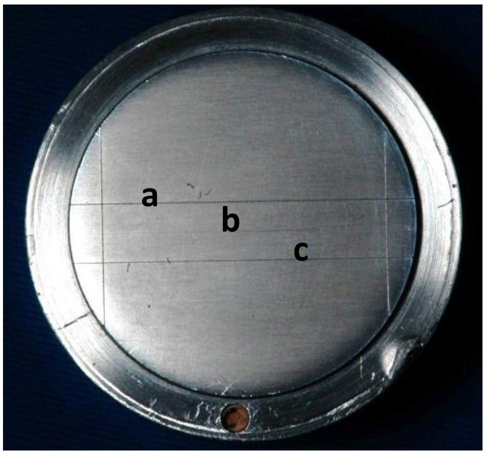

Fig. 1. The ruled test block with lines a (50µm), b (20 µm) and c (75 µm).

3.2 Materials

The following alginate materials were used:

Cavex Impressional (Cavex Holland BV, Netherlands)

Plastalgin (SEPTODONT, Cedex, France)

Essential range (Wright Cottrell, Dundee, U.K)

Blueprint 20+ (DENTSPLY Detrey Gmbh, Germany)

Neocolloid (Zhermack, Rovigo, Italy)

Kromogel Plus (Wright Cottrell, Dundee, U.K)

The following gypsum materials were used:

Dental stone class 3 (Wiegelmann Dental, Bonn, Germany)

Royal rock blue class 5 (Wiegelmann Dental, Bonn, Germany)

Satin stone class 5 (Wiegelmann Dental, Bonn, Germany)

Die stone peach class 4 (Wiegelmann Dental, Bonn, Germany)

Kaldent white class 2 (Kalabhai Karson Pvt Ltd, Mumbai, India)

Kalstone yellow class 3 (Kalabhai Karson Pvt Ltd, Mumbai, India)

All materials were from the same batch per material. Three tests of each alginate were carried out on each type of gypsum to provide 36 possible combinations.

3.3 Method

Measuring containers provided in each packet of alginate were used to dispense quantities recommended by the manufacturer. Distilled water was used for the mixing of both alginates and gypsum materials and the room temperature was controlled to 22±1º. Measurement of the distilled water was carried out using a 20ml plastic syringe. A suitable large base for the alginate impression mould was made using a glass slab and cotton gauze and adhesive tape (Figure 2). The glass slab provided a solid base for the alginate while the taped cotton gauze stabilised the alginate impression on the slippery glass slab.

Fig. 2. The alginate mould on a base of gauze on a glass slab

Hand spatulation was used to mix the different alginate materials according to the specifications of each manufacturer. In a study reported by Reisbick et al (1982), there were no major added benefits to using mechanical mixing of alginate. Furthermore, hand spatulation is more representative of the clinical setting in the majority of dental practices. Similarly, water temperature was set at 21±1° throughout as there were no differences in accuracy for water ranging between 3, 10 and 20ºC (Harris, 1969).

The surface of the test block is smooth and it was found that some alginates tended to stick to it, and so the surface was lubricated with a thin layer of the researcher's saliva (which in fact mimics the clinical situation). The test states that a separating agent can be used (BSI 1991). The appropriate mould was slightly overfilled with alginate and the test block was pressed into it. This assembly was then immediately placed in a water-bath kept at 32ºC to simulate the humidity of the oral environment. A weight of 1kg was loaded onto this assembly as per the test (Figure 3) until the setting time of the alginate plus one minute had elapsed.

Fig. 3. The standard die placed on the alginate mould, immersed in water, and with a 1kg weight placed on the die.

The standard die was then detached from the alginate mould to allow for inspection of the lines on the alginate surface. Distilled water was used to rinse the alginate surface and any excess shaken off. The reproduced lines were noted subjectively; if there were no lines seen on the alginate surface, the procedure was repeated. The set alginate remained over the damp cotton gauze to maintain 100% humidity whilst the gypsum product was being mixed. Thus, by the time the gypsum was poured, the alginate would have stayed for approximately 4 minutes after its setting time.

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Unlike the alginate, gypsum has been found to mix better with less porosity, when subjected to a mechanical vacuum mixer (Jorgenson & Kono, 1971). The correct amount of gypsum powder as recommended by the manufacturer of each gypsum product was weighed on a digital dietetic scale (Modern Scale Co. Pty Ltd, SA) and the corresponding recommended amount of distilled water was measured and dispensed using a 20ml syringe. The scale measures from 0.5g to 1000g. The gypsum quantity that was required to fill up the gypsum mould worked out to be 40g and the corresponding volume of distilled water calculated accordingly as shown in Table 1.

Table 1. Gypsum & Water ratios & expected setting times.

Gypsum Product	Powder : Water Ratio	Setting Time
White Dental stone class 3	40g: 11ml	14minutes
Yellow Royal rock blue class 5	40g : 7.5ml	16minutes
Satin stone class 5	40g : 8ml	23minutes
Die stone peach class 4	40g : 8 ml	15minutes
Kaldent white class 2	40g : 18ml	17minutes
Kalstone yellow class 3	40g : 11ml	16minutes

A gypsum mould is supplied as part of the ISO standard die kit and this was used, after lubricating the inside of it lightly with Vaseline. This gypsum mould was placed over the alginate mould that contained the impression. A vibrator was used to facilitate close flowing of the gypsum over the alginate surface (Figure 4). Caution was taken to ensure that the alginate was orientated beneath the gypsum for good cast surfaces to be obtained (Young, 1965).

Fig. 4. Left: gypsum mould(with a lubricated interior) fitted over the alginate mould containing the set alginate; Middle: the same assembly with the gypsum poured in on top of a vibrator; Right: the filled gypsum mould waiting for complete setting of the gypsum.

Within the pilot study, the setting times of the gypsum products were established in line with the manufacturer’s recommendations, and an additional 30 minutes were allowed for the gypsum product mix to harden in excess of the setting time, as prescribed by the ISO standard.

Once the gypsum casts were set and separated, the ISO standard requires them to be viewed under low-angle illumination. The line required to be reproduced by alginate is the 50µm line. Photomicrographs of the cast surfaces were taken under 4 x magnification using a camera fixed to a Zeiss surgical microscope. Illuminating light was shone at a consistent angle towards the 50µm line for all dies. The same operator (primary researcher), made all the impressions, cast the models and took the pictures of the casts with the help of an assistant. A practice run was conducted until the primary researcher was confident enough to produce consistent results. Photographs were taken by ensuring that the entire 25mm length of the 50µm line was captured as seen between the cross lines on either side of the die. The three test lines on the die look very similar to the naked eye and so a dimple was drilled on the die surface to the right of the 50µm line. This assisted in identifying the line on the gypsum die surface and it made it easier for the consistent orientation of the die during photography.

Any casts with obvious distortions such as those due to poor operator handling were excluded from the final sample and more were made; eventually the best two casts for each combination were chosen after the photomicrographs were taken. Any imperfections that were obviously from minor mixing errors, such as an air bubble in the plaster or a “bobble” on the plaster which would have been an air bubble in the Alginate were ignored. The photographs were coded and imported into Microsoft PowerPoint software for evaluation. A four-category scoring system was devised which would take into account both the quality of the surface of the gypsum cast, and the reproducibility of the 50µm (Table 2 and Figures 5 to 8).

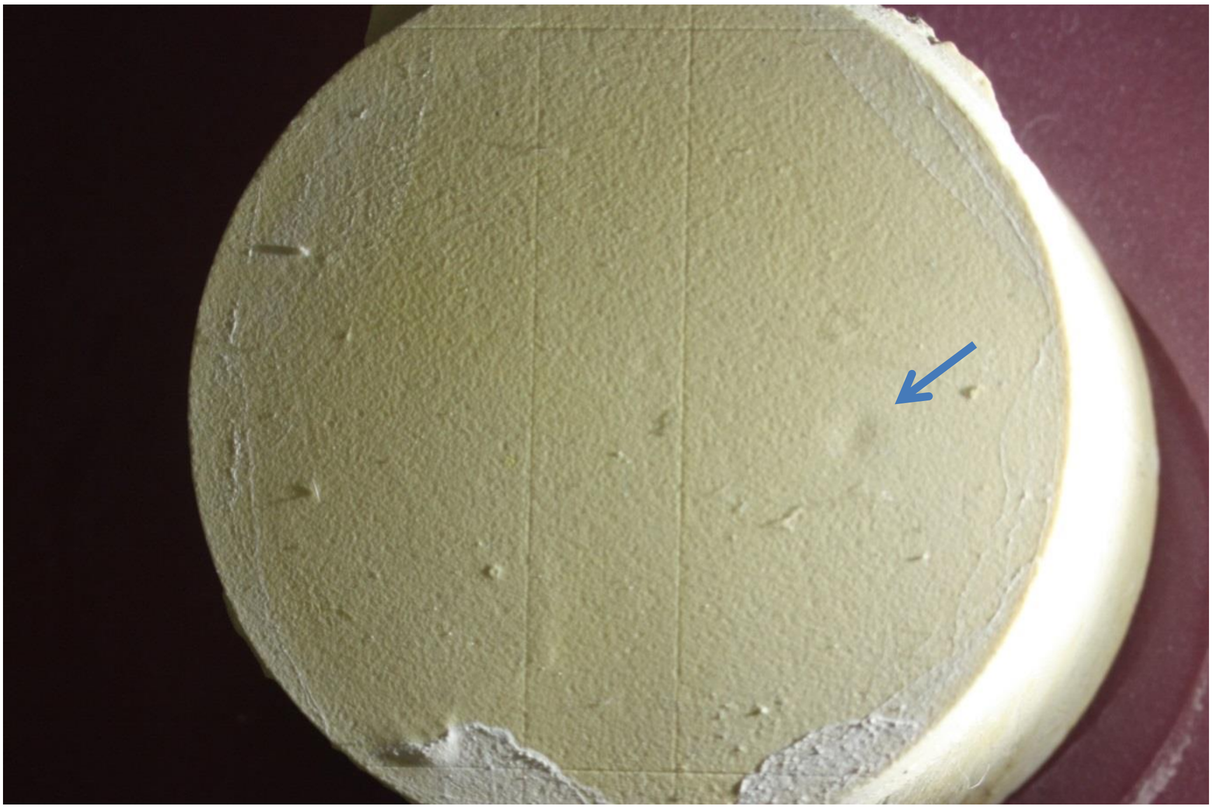

Fig. 5. This cast received a score of 1: the entire line is visible and continuous. The arrow shows the small dimple produced to identify the 50µm line as being the one nearest to the dimple. This was made after it was found that some casts were difficult to identify.

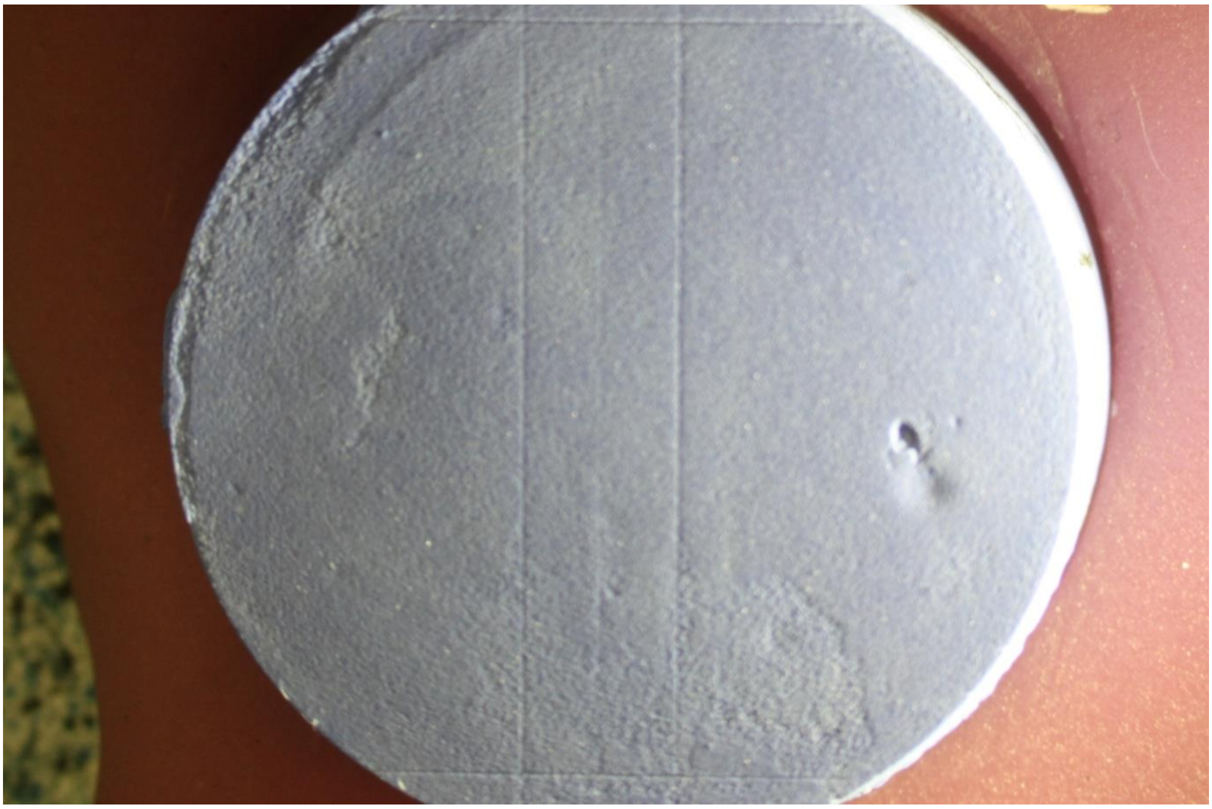

Fig. 6. This cast received a score of 2: 75% of the line is continuous, 25% with some imperfections

Fig. 7. This cast received a score of 3: 50% of the line is continuous, 50% appearing indistinct

Fig. 8. This cast received a score of 4: More than 50% of the line cannot be seen properly or the line can hardly be seen at all

Four raters were first calibrated by showing them examples of four categories of the score as a colour print-out from the PowerPoint slides. They were shown a random selection of 10% of the slides. The sums of these scores were subjected to a statistical analysis to establish intra- and inter-examiner consistency using the SAS statistical package (SAS Institute Inc., SAS Software, version 9.3 for Windows, Cary, NC, USA: SAS Institute Inc. 2002-2010).

The coded slides were shuffled around before each round of evaluations. Two days were allowed between the scoring exercises to remove the bias of memory and light-reflective effects.

A variety of statistical tests was applied to the data to first analyse intra- and inter-rater reliability to determine the acceptability of using combined or averaged scores, and then to ascertain significant interactions between the alginates and the gypsum products. All statistical tests were carried out at the 0.05 significance level. The tests included Bowker, (1948), which is a test of symmetry in the data, Cohen’s kappa which determined if there was a purely chance agreement on rating and the measurement of the agreement of kappa as reported by Landis & Koch, 1977.

The raw data are appended as an addendum.

CHAPTER 4. RESULTS

4.1 Intra-and Inter-rater reliability

This analysis was conducted on the directly observed Q-score data. Bowker's test of symmetry (Bowker, 1948), if significant, indicates that the raters are selecting the categories in differing proportions, if not significant, the cell proportions in the cross-tabulation of the ratings would be symmetric. To determine whether there was a purely chance agreement on rating, Cohen's kappa was applied. As the data are ordinal the quadratically weighted kappa was used (Cohen, 1968). The magnitude of kappa was interpreted based on a classification by Landis & Koch (1977).

4.1.1 Intra-rater reliability

These analyses represent how well the ratings on each of the three occasions agreed for each rater individually.

Table 3. Rater A Q-scores (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Observation 1	Observation 2	Observation 3
Observation 1		86% NS	82% NS
Observation 2	0.91 (0.83-0.99) almost perfect		85% NS
Observation 3	0.91 (0.86-0.97) almost perfect	0.89 (0.81-0.98) almost perfect	

Table 4. Rater B Q-scores (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Observation 1	Observation 2	Observation 3
Observation 1		65% NS	69% NS
Observation 2	0.84 (0.76-0.92) almost perfect		86% NS
Observation 3	0.83 (0.75-0.92) almost perfect	0.95 (0.91-0.98) almost perfect	

Table 5. Rater C Q-scores (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Observation 1	Observation 2	Observation 3
Observation 1		74% NS	64% Sig
Observation 2	0.80 (0.68-0.90) substantial		76% NS
Observation 3	0.73 (0.61-0.85) substantial	0.82 (0.70-0.93) almost perfect	

Table 6. Rater D Q-scores (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Observation 1	Observation 2	Observation 3
Observation 1		57% Sig	60% Sig
Observation 2	0.70 (0.56-0.84) substantial		86% NS
Observation 3	0.67 (0.51-0.82) substantial	0.92 (0.86-0.98) almost perfect	

Inspection of the raw data shows that most of the specimens were rated in the extreme categories (1 and 4). Not surprisingly, rater A (the principal researcher) had the highest intra-rater reliability when considering all three measures together. Raters B, C and D had their best percentage agreement and kappa scores between the second and third observations, suggesting that as they became more familiar with the rating scale and process, their individual ratings became more consistent. For evaluator C, the ratings tended to increase along the ordinal scale from 1 to 4 from the first to the second observation and for evaluator D, the ratings tended to decrease from the first to the second, and from the first to the third observation. This suggests that these evaluators were not applying the rating scale entirely consistently from the start of the rating process.

4.1.2 Inter-rater reliability

The measure of how well the observations from each of the four raters agreed on each occasion is presented in Tables 6 to 8.

Table 7. Reliability statistics for Observation 1 (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Rater A	Rater B	Rater C	Rater D
Rater A		60% NS	65% Sig	75% NS
Rater B	0.70 (0.56-0.84) substantial		60% Sig	63% NS
Rater C	0.71 (0.56-0.86) substantial	0.69 (0.55-0.83) substantial		61% Sig
Rater D	0.89 (0.82-0.95) almost perfect	0.77 (0.65-0.88) substantial	0.75 (0.63-0.87) substantial	

Table 8. Reliability Statistics for Observation 2 (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Rater A	Rater B	Rater C	Rater D
Rater A		65% Sig	68% NS	67% NS
Rater B	0.77 (0.65-0.88) substantial		64% Sig	61% NS
Rater C	0.72 (0.57-0.87) substantial	0.81 (0.71-0.92) almost perfect		71% NS
Rater D	0.74 (0.60-0.88) substantial	0.85 (0.79-0.91) almost perfect	0.81 (0.71-0.91) almost perfect	

Table 9. Reliability Statistics for Observation 3 (n=72). Percentage agreement with Bowker's test (NS = not significant) and weighted kappa (95% confidence interval) with interpretation of level of agreement.

	Rater A	Rater B	Rater C	Rater D
Rater A		60% Sig	72% NS	71% Sig
Rater B	0.72 (0.60-0.84) substantial		65% Sig	60% Sig
Rater C	0.80 (0.67-0.92) substantial	0.75 (0.63-0.87) substantial		68% NS
Rater D	0.68 (0.52-0.84) substantial	0.81 (0.73-0.89) almost perfect	0.71 (0.55-0.86) substantial	

Overall, the percentage agreement between raters for the same occasion ranged between 60% and 75%. Kappa values ranged from 0.69-0.89 which are interpreted as substantial agreement or better. No evidence of an improvement in inter-rater reliability over time was noted. Based on this, there was justification for use of results from all three rounds of observation without excluding results of any one round. The comparisons for which Bowker's test of symmetry was significant indicate that the evaluators may not have been trained sufficiently in the use of the rating scale or that the rating scale had insufficient discrimination.

In order to test the extent of the inter-rater variability, alginate/gypsum combinations per rater which differed by more than one point are shown in Table 10 in line with Owen (1986b).

Table 10. Alginate/gypsum combinations per rater, differing by more than one point over three observations. Those differing by more than two points are highlighted.

Alginate	Gypsum	Replicate	Rater	Obs1	Obs2	Obs3
Cavex Impressional	Dental stone class 3	2	C	1	3	3
			D	1	4	4
	Royal rock blue class 5	1	A	2	4	2
		2	D	1	2	4
	Die stone peach class 4	1	B	2	3	4
			D	1	4	4
	Die stone peach class 4	2	B	1	3	3
			D	1	4	4
	Kaldent white class 2	1	D	1	3	3
		2	C	2	4	1
			D	3	2	1
	Kalstone yellow class 3	1	A	2	4	3
Plastalgin	Die stone peach class 4	1	A	1	4	1
	Kaldent white class 2	1	C	4	1	1
	Kalstone yellow class 3	2	B	4	2	2
Essential range	Kaldent white class 2	1	C	4	4	1
		2	C	4	3	2
Blueprint 20+	Dental stone class 3	1	A	3	2	1
			C	3	2	1
			D	2	4	4
		2	C	4	2	2
			D	2	2	4
	Royal rock blue class 5	1	A	4	4	2
		2	A	4	4	2
			C	3	4	1
	Kaldent white class 2	1	C	3	4	2
			D	2	2	4
Neocolloid	Dental stone class 3	1	C	4	2	2
		2	C	3	1	1
	Kaldent white class 2	1	C	4	2	3
	Kalstone yellow class 3	2	C	3	1	1
Kromogel plus	Kalstone yellow class 3	1	C	4	4	2
			D	2	4	4

(Replicate = one of the prepared casts, 3 replicates made for each alginate-gypsum combination and two kept for evaluation by observers).

There were 9 (3.1%) combinations that differed by more than two points and 33 (11.5%) that differed by more than one point within raters.

4.2 Analysis of combined Q-Score data

The frequency distribution of the scores obtained by summing the three scores of each rater for each specimen is shown in Figure 9.

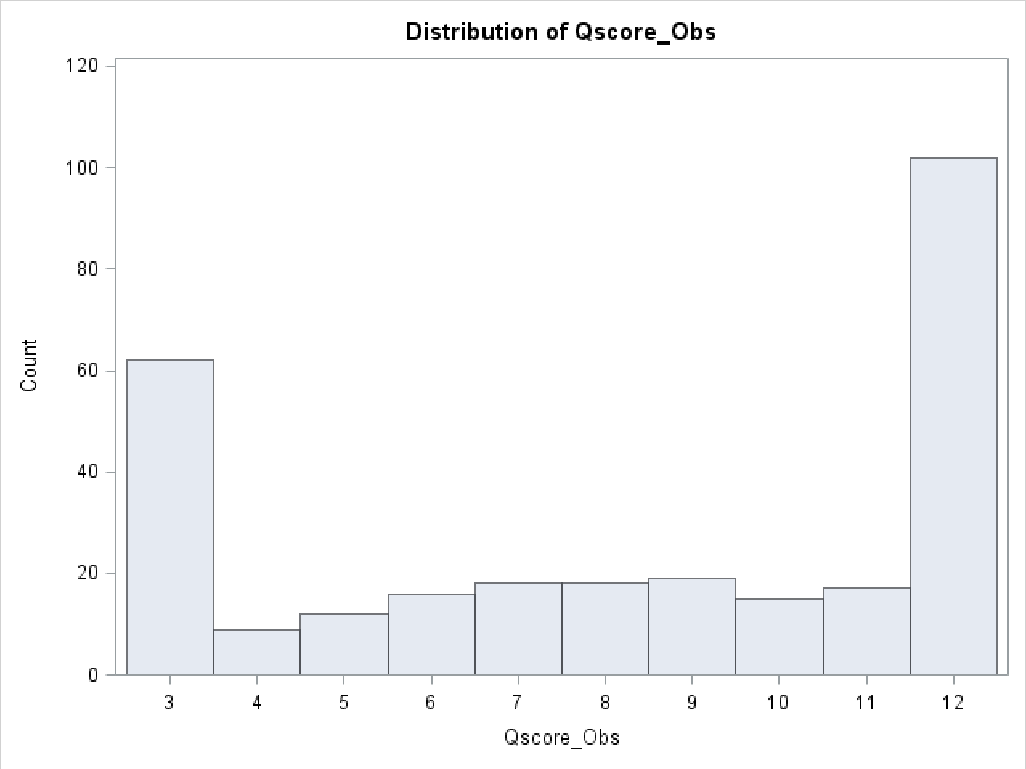

Fig. 9. The frequency distribution of the Q-scores

This confirms the fact that the bulk of the scores fell into the two extreme categories of 1 and 4, now summed to scores of 3 and 12, respectively.

In order to determine the effect of rater on alginate, gypsum, and more importantly, the alginate/gypsum combinations, a three-way analysis of variance (ANOVA) was carried out, shown in Table 10. The ordinal nature of the data was confirmed in that assumptions of normality were not met and so a non-parametric rank test was applied to test for significance.

Table 11. Summary of the 3 way ANOVA with factors alginate, gypsum and rater, to determine the rater effect.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Alginate	5	488218	97644	55.75	<.0001
Gypsum	5	498007	99601	56.87	<.0001
Alginate*Gypsum	25	528344	21134	12.07	<.0001
Rater	3	14827	4942	2.82	0.041
Alginate*Rater	15	15353	1024	0.58	0.88
Gypsum* Rater	15	27398	1827	1.04	0.42
Alginate*Gypsum* Rater	75	55229	736	0.42	1.00
Residual	144	252206	1751	.	.

Despite the differences in the scores between raters, there was no significant interaction between rater and alginate, gypsum, and alginate/gypsum combinations. To confirm this, the raters were then considered as random, rather than fixed effects, the results of which are shown in Table 11.

Table 12: Components of Variance estimated from the mixed model.

Source	Estimated variance
Alginate	0.077
Gypsum	0.095
Alginate*Gypsum	0.37
Rater	0.072
Alginate* Rater	0
Gypsum*Rater	0.086
Alginate*Gypsum* Rater	0

As with the fixed effects model, the variance associated with the interaction between the raters and alginate, gypsum, and alginate/gypsum combinations is relatively small. It is reasonable to conclude that significant effects of interest will not be obscured by the inter-rater variability, and can be considered to be independent of the rater effect.

The Q-scores were now averaged across all four raters and these mean scores for each replicate experiment (two prints were scored for each alginate/gypsum combination thus generating two replicates per combination) are shown in Table 12, and their frequency distribution is shown in Figure 10.

Table 13. The mean scores for each replicate experiment

Alginate	Gypsum						Marginal mean: Alginates
	Gyp 1 Dental stone class 3	**Gyp 2** Royal rock blue class 5	**Gyp 3** Satin stone class 5	**Gyp 4** Die stone peach class 4	**Gyp 5** Kaldent white class 2	**Gyp 6** Kalstone yellow class 3	
Alg 1 Cavex Impressional	3.00	6.75	12.00	8.25	5.50	9.50	7.15
	7.25	5.75	12.00	5.75	5.75	4.25	
Alg 2 Plastalgin	9.00	3.00	12.00	4.00	4.75	4.00	5.73
	8.75	3.00	3.50	3.50	6.25	7.00	
Alg 3 Essential range	6.50	11.75	12.00	9.75	9.00	11.25	10.63
	12.00	12.00	12.00	12.00	7.75	11.50	
Alg 4 Blueprint 20+	7.75	10.00	12.00	12.00	6.25	3.25	8.40
	7.75	9.75	12.00	12.00	5.00	3.00	
Alg 5 Neocolloid	8.50	3.00	12.00	11.00	7.00	3.00	7.21
	5.75	3.00	12.00	8.75	8.00	4.50	
Alg 6 Kromogel plus	12.00	12.00	12.00	12.00	3.50	10.75	10.48
	12.00	12.00	12.00	12.00	3.75	11.75	
Marginal mean: gypsum	8.35	7.67	11.29	9.25	6.04	6.98	8.26

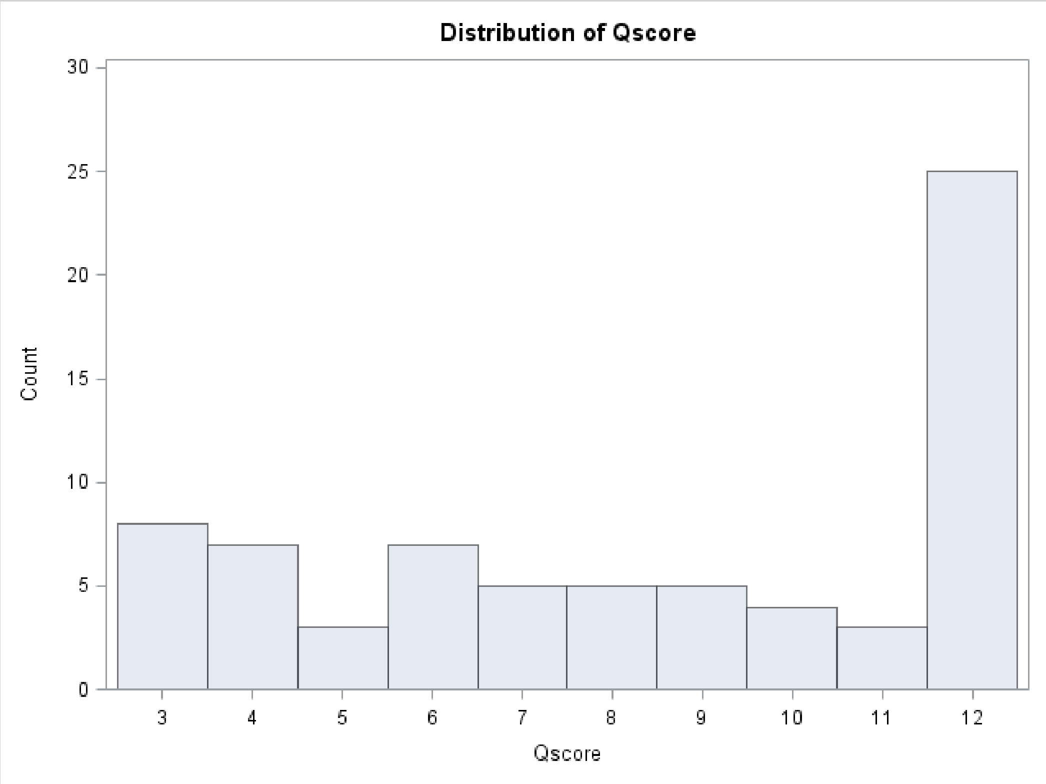

Fig. 10. The frequency distribution of the mean scores for each replicate experiment

These scores were now subjected to a two-way analysis of variance, where it was found that the model explained 88% of the variance in the data. The results are shown in Table 13.

Table 14. Results of the 2-way ANOVA on the mean scores

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Alginate	5	231	46	17.33	<.0001
Gypsum	5	205	41	15.35	<.0001
Alginate*Gypsum	25	291	12	4.36	<.0001
Error	36	96	2.7	.	.

The effects of the two main factors of alginate and gypsum and their interaction were, as expected, highly significant. The interaction as the main interest, was then plotted for alginates against gypsums: a low mean for any combination corresponds to high compatibility (the lowest mean is 3 and the highest 12). This is shown in Figure 11, where the error bars have been shown for only two series for clarity, but apply to all.

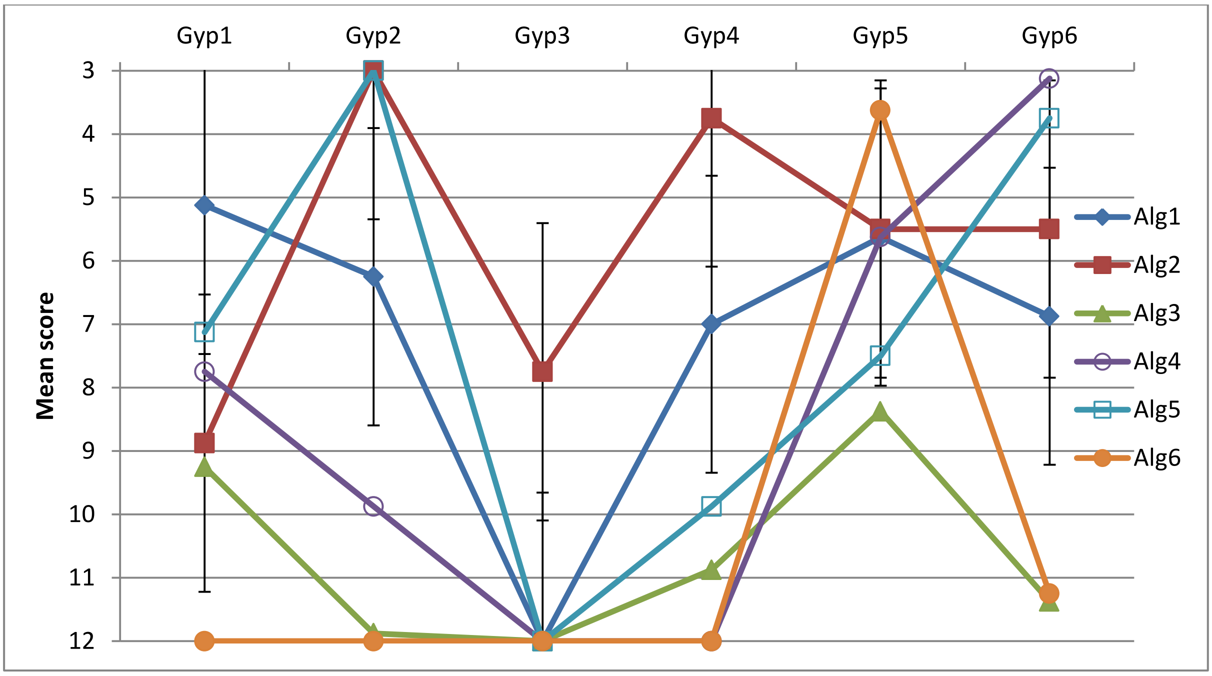

Fig. 11. Interaction plot for the alginate/gypsum combinations. The error bars denote 95% confidence intervals for the means

The high variability between the replicates as well as between raters made it difficult to find distinct groups of alginate/gypsum combinations, except at the extremes of the scoring range. Post-hoc tests using the Tukey-Kramer adjustment were used to try to identify significantly different alginate/gypsum combinations. However, the number of the pairwise comparisons was too large and it was decided to focus on the alginate/gypsum combinations with scores below or equal to 7.5, being the midpoint of the scoring range. The least-squares (LS) means for each alginate/gypsum combination in order from best to worst Q-score are shown in Table 14.

Table 15. List of the least-squares means (LSMEAN) for each alginate/gypsum combination in order from best to worst Q-score

Alginate	Gypsum	Q-score LSMEAN
Neocolloid	Royal rock blue class 5	3.00
Plastalgin	Royal rock blue class 5	3.00
Blueprint 20+	Kalstone yellow class 3	3.13
Kromogel Plus	Kaldent white class 2	3.63
Plastalgin	Die stone peach class 4	3.75
Neocolloid	Kalstone yellow class 3	3.75
Cavex Impressional	Dental Stone class 3	5.13
Plastalgin	Kaldent white class 2	5.50
Plastalgin	Kalstone yellow class 3	5.50
Cavex Impressional	Kaldent white class 2	5.63
Blueprint 20+	Kaldent white class 2	5.63
Cavex Impressional	Royal rock blue class 5	6.25
Cavex Impressional	Kalstone yellow class 3	6.88
Cavex Impressional	Die stone peach class 4	7.00
Neocolloid	Dental Stone class 3	7.13
Neocolloid	Kaldent white class 2	7.50
Plastalgin	Satin stone class 5	7.75
Blueprint 20+	Dental Stone class 3	7.75
Essential range	Kaldent white class 2	8.38
Plastalgin	Dental Stone class 3	8.88
Essential range	Dental Stone class 3	9.25
Blueprint 20+	Royal rock blue class 5	9.88
Neocolloid	Die stone peach class 4	9.88
Essential range	Die stone peach class 4	10.88
Kromogel Plus	Kalstone yellow class 3	11.25
Essential range	Kalstone yellow class 3	11.38
Essential range	Royal rock blue class 5	11.88
Cavex Impressional	Satin stone class 5	12.00
Essential range	Satin stone class 5	12.00
Kromogel Plus	Satin stone class 5	12.00
Blueprint 20+	Satin stone class 5	12.00
Neocolloid	Satin stone class 5	12.00
Kromogel Plus	Dental Stone class 3	12.00
Blueprint 20+	Die stone peach class 4	12.00
Kromogel Plus	Royal rock blue class 5	12.00
Kromogel Plus	Die stone peach class 4	12.00

Significant differences are denoted by the bars: the bottom of each bar shows the first combination which is significantly different from the combination indicated by the top of the bar. All combinations within the bars are therefore not significantly different from each other, and from the combinations with a score of 5.50 or worse, there are no significant differences with any other combinations.

When the alginates are considered on their own, their average performance over all the gypsums tested, can be graphically shown as in Figure 12

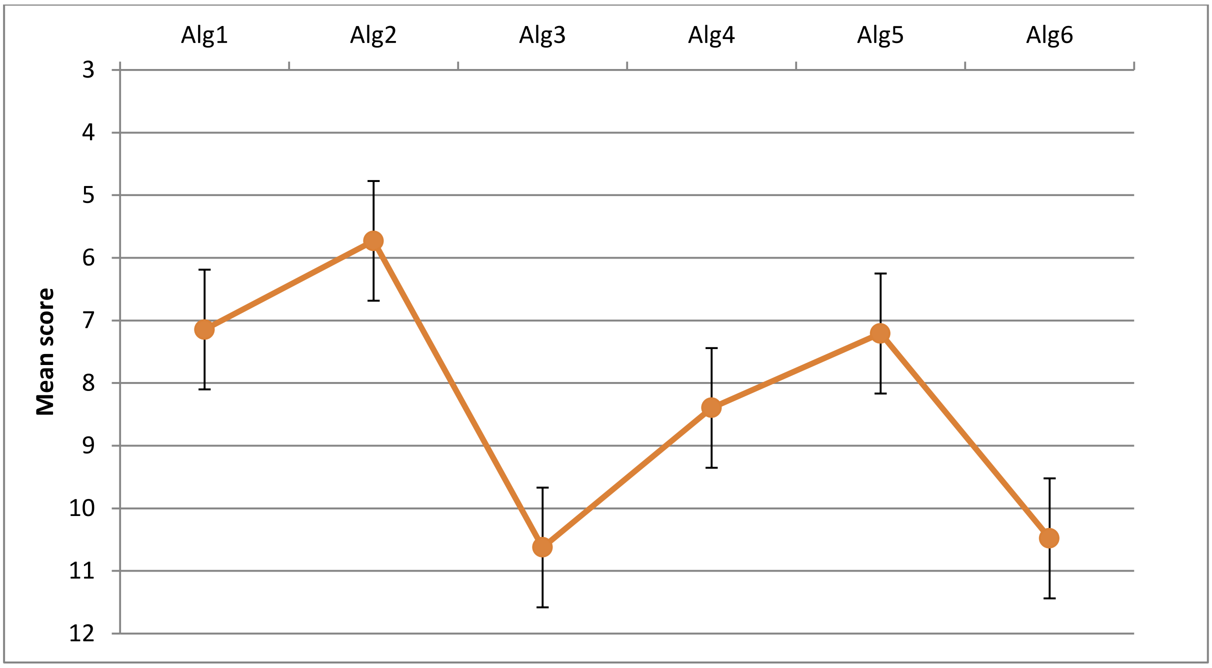

Fig. 12. Graph depicting the mean scores of the alginates across all the gypsum. Bars represent their 95% confidence intervals. (Alg1: Cavex Impressional; Alg2: Plastalgin; Alg3: Essential range; Alg4: Blueprint 20+; Alg 5: Neocolloid; Alg6: Kromogel Plus)

Post-hoc tests using the Tukey-Kramer adjustment identified the following significant differences:

- Alg6 (Kromogel Plus) and Alg3 (Essential Range) were the worst-performing alginates but were not significantly different to each other. Both scored significantly lower than the other four alginates.
- Alg2 (Plastalgin) performed significantly better than Alg3 (Essential Range), Alg4 (Blueprint 20+) and Alg6 (Kromogel Plus).
- There was no significant difference between the scores of any of the other alginates.

When the gypsums were considered by themselves, their average performance across all the alginates is depicted in Figure 13:

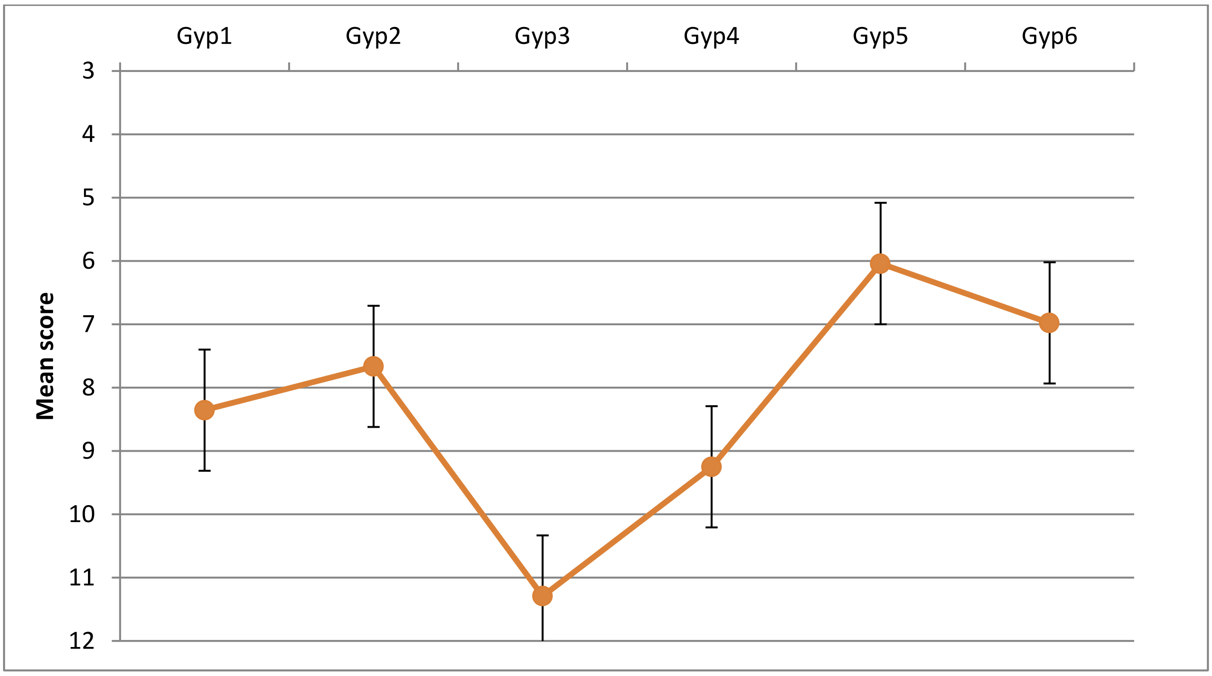

Fig. 13. Graph depicting the mean scores of the gypsums across all the alginates. Bars represent their 95% confidence intervals (Gyp1: Dental Stone class 3; Gyp2: Royal rock blue class 5; Gyp3: Satin stone class 5; Gyp4: Die stone peach class 4; Gyp5: Kaldent white class 2; Gyp6: Kalstone yellow class 3)

Post-hoc tests using the Tukey-Kramer adjustment showed the following significant differences:

- Gyp3 (Satin stone) performed significantly worse than all the other gypsums.
- Gyp5 (Kaldent White) performed significantly better than Gyp1(Dental Stone), Gyp3 (Satin stone) and Gyp4 (Die stone peach).
- Gyp6 (Kalstone yellow) performed significantly better than Gyp3(Satin stone) and Gyp4 (Die stone peach).

There was no significant difference between the scores of any of the other gypsum products.

CHAPTER 5. DISCUSSION

The relevant section in the standard for the "compatibility with gypsum and reproduction of detail" (BSI 1991) states that "*The impression material shall impart a smooth surface to, and separate cleanly from, a gypsum cast made from a recommended brand of gypsum product; this cast poured against the impression shall reproduce the 50 µm line without interruption when the test specified is carried out*." (BSI 1991). The specified test is as per the method described and used in this study, but the evaluation of the line is merely described as "*Record whether the 50 µm-line is fully reproduced by at least two casts, resulting from three tests*." (BSI 1991).

Previous studies (Young, 1965; Harris, 1969) have shown, however, that such a description does not necessarily discriminate sufficiently for the variations observed clinically in the quality of gypsum casts when cast against an alginate. In light of the fact that alginate impressions are used for a variety of purposes from diagnostic casts to final casts used for more precise work such as during the manufacture of metal frameworks for removable partial dentures, it is essential for the clinician to know that the alginates and gypsums used are not only compatible, but able to produce detail and with an appropriate quality of surface.

The purpose of this study was to test a variety of readily available alginate products against a variety of gypsum products also readily available, to make recommendations as to the most appropriate alginate/gypsum combinations.

It was found that there was a wide variation in the quality of the gypsum surfaces produced, and in the ability of the alginate/gypsum combinations to reproduce the 50µm line throughout its length and with a consistent quality.

The scoring method devised to provide for better discrimination between the different combinations proved to be less successful than a previous similar method (Owen 1986b), which was evident from the intra- and inter-rater variability encountered. This variability may be an indication of the inconsistencies in the alginate/gypsum interactions, such that the rating's ability to discriminate between the middle categories was poor. On the other hand, the variability between the raters is harder to understand, when some raters categorised the same combination as a 1 on one occasion, and a 4 on another. This may be an expression of the rating scale's descriptors being insufficiently precise, or that the raters were not sufficiently trained or even conscientious enough, or a combination of these factors.

Nevertheless, despite these limitations, there were sufficient data to produce statistical analyses that justified the use of combination means, although the rater variability was always going to make it difficult to find significantly distinct groups of alginate/gypsum combinations, except at the extremes of the scoring range, and this proved to be the case. The value of this study, then, lies in finding those combinations which had the best (lowest) and most consistent scores. Referring to Table 15, it is then possible to select combinations based on the requirements of the cast. For example, a cast for diagnostic purposes would not normally be produced in a type 4 or 5 dental stone, nor would a cast on which resin-based dentures are made. The normal gypsum product for these purposes would be yellow stone, represented here by the product Kalstone Yellow, a Class 3 gypsum. However, when a cast is to be used in the manufacture of a metal framework for a removable partial denture, then a Class 4 or 5 stone is required, represented by the products Royal Rock Blue (Class 5), Satin stone (Class 5) and Die Stone Peach (Class 4).

Although there were no statistically significant differences between the combination means, it would seem logical to limit the acceptable combinations to those with a mean score of 4 or less, as indicated in Table 15. Hence if a Class 3 stone cast is required, this means the following combinations should be used:

- Kalstone Yellow with Blueprint 20+ (mean score 3.13) or with Neocolloid (mean score 3.75)

If a Class 5 cast is required, the following combinations apply:

- Royal Rock Blue with Neocolloid (mean score 3.0) or with Plastalgin (mean score 3.0)
- Die Stone Peach with Plastalgin (mean score 3.75)

Study casts are often made with a combination of Yellow stone and White plaster, and although this combination of gypsums was not tested, it would seem that it may not produce the best casts because Blueprint 20+ combined well with Kalstone Yellow stone (mean score 3.13) but not with Kaldent White (mean score 5.63) and Kromogel combined well with Kaldent White (mean score 3.63) but not with Yellow Stone (mean score 11.25).

Of some concern was that there were combinations of alginate and gypsum which showed extremely poor compatibility and scored in the category where the surface quality was unacceptable and the ability to reproduce a line on the standard die was such that the line could hardly be made out. Plastalgin was the only alginate that did not enter into this category and Kaldent White the only gypsum.

CHAPTER 6. CONCLUSION

The EN 21563:1991 (ISO1563:1990) standard stipulates a number of tests for alginate materials but only the compatibility with gypsum and reproduction of detail marked the interest for this study. An attempt was made to produce a higher discrimination between various combinations of alginate and gypsum, but the study was limited by the variability encountered between the raters of the quality of the reproduction of the standard die used. Statistically it was possible to use combination means from all the raters, and within the limitation of the rater variability, it is possible to recommend the following combinations of alginate and gypsum:

For a cast using a type 3 gypsum product for study models and on which resin-based prostheses may be made:

- Kalstone Yellow with Blueprint 20+ or with Neocolloid

For a cast using type 4 or 5 dental stone which can be used in the process of making metal frameworks for removable partial dentures:

- Royal Rock Blue with Neocolloid or with Plastalgin
- Die Stone Peach with Plastalgin

The fact that there were 9 combinations which scored in the very worst category means that manufacturers of alginates should recommend specific gypsum products with which they are compatible and which were used to obtain their ISO rating, and clinicians should be more aware of the need for compatibility.

CHAPTER 7. REFERENCES

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Addendum 2: The ISO standard