An Investigation into the Accuracy of Two Currently Available Dental Impression Materials in the Construction of Cobalt-Chromium Frameworks for Removable Partial Dentures

Keywords

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ABSTRACT

This study investigated the suitability of irreversible hydrocolloid as an impression material for cobalt-chromium framework construction. Scans of casts derived from (1) alginate and (2) addition-cured polyvinylsiloxane impressions were superposed on to a control. The differences within and between groups were compared at fixed landmarks.

The investigation revealed a high degree of scan coincidence within and between groups. However, certain features, such as undercuts, resulted in a lower degree of scan coincidence.

Irreversible hydrocolloid appears to be a viable alternative to addition-cured polyvinylsiloxane as an impression material for cobalt-chromium framework construction.

INTRODUCTION

Removable partial prostheses are commonly used today to restore appearance, speech and mastication following tooth loss. Irrespective of declining levels of tooth loss (Adult Dental Health Survey, 2009)[1], the need for removable partial prostheses remains, as the population ages.

Irreversible hydrocolloid is the most commonly used impression material in the world[2,3,4]. It enjoys considerable use as an impression material for the provision of master casts used in cobalt-chromium framework construction[5,6,7,8] and has done so for many years[9]. In a questionnaire-based study of dental laboratories[5], Kilfeather *et al* (2009) found that 58% of master impressions recorded for cobalt-chromium framework construction were made using alginate. Other studies have reported between 33%[6,7] and 71%[8] of impressions being recorded in alginate for this purpose. Contemporary teaching recommends the use of addition-cured polyvinylsiloxane (silicone) instead, as a result of its greater dimensional accuracy and stability. A search of the literature did not reveal support for the use of alginate as an impression material for cobalt-chromium framework construction.

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Alginate remains popular as an impression material, as it is cheap, biocompatible, accurate, easy to mix, hydrophilic and exhibits favourable working and setting times. Allergic reactions are seldom observed, and the material is biodegradable and renewable. Disadvantages of alginates include poor dimensional stability,[10,11,12] following the effects of syneresis and imbibition, so impressions need to be poured up soon after setting[11]. It has been shown that alginates may be stored in 100% humidity for up to three hours without significant changes to the accuracy of resultant casts[12].

Alginates also exhibit poor tear strength and may distort upon removal from deep undercuts,[13] which has been shown to result in inaccuracy of the resulting cast[14,15]. This inherent weakness of alginates does not allow for multiple casts to be poured from the same impression. In contrast to this, silicone impressions are known to be very accurate, strong and exhibit good tear resistance. It has been shown that there is no significant dimensional change in casts obtained by using addition-cured silicone impression materials in the presence of deep undercuts[15]. Dimensional stability of up to thirty days has been reported[17]. This strength coupled with excellent dimensional stability allows for multiple casts to be poured up from a single impression, and this is possible after a considerable storage time[16]. Disadvantages of silicone impressions include hydrophobicity[18]. The best surface detail reproduction occurs when this material is used in relatively dry conditions[19]. In addition to this, they are expensive and they can be messy to use. A variable setting time of between three and six minutes has been reported[20], and is generally considerably longer than that of alginates. Silicone impressions have a very long half-life and as such can prove difficult to cleanly destroy.

A search of the literature did not reveal any evidence to support or reject the use of alginate for the construction of cobalt-chromium frameworks. However their use has been reported with regards to the construction of fixed prosthodontics[21]. In this study, Eriksson *et al* found that irreversible hydrocolloid when mixed mechanically, without a vacuum, using a tray identical in design to a perforated stock tray and poured up within two hours provided accuracy similar to the tested reversible hydrocolloid and addition cured polyvinylsiloxane materials[21]. However, there does not appear to be literature comparing the casts resulting from each impression material for the purpose of cobalt-chromium framework construction. The aim of this study therefore was to investigate the use of irreversible hydrocolloid as a definitive impression material for cobalt-chromium framework construction.

The objective was to compare, by superposition, scans obtained of casts derived by alginate and silicone impressions, and to quantify the differences. It is anticipated that the differences within and between the groups will provide some indication as to the accuracy of reproduction when using alginate impression material for recording master impressions for cobalt-chromium framework construction.

The null hypothesis proposed is that there is no difference in the dimensional accuracy between casts produced from alginate and addition cured polyvinylsiloxane impressions when they are superposed.

MATERIALS AND METHODS

A mandibular Kennedy Class II modification I cast was selected as a test cast as it possessed the potential for a wide variety of dental and soft tissue features, including prepared tooth rest seats, a free-end saddle and a bounded saddle.

The cast was surveyed and an appropriate cobalt-chromium framework partial denture design was established. Appropriate rest seats were prepared in the cast, together with a tripod of stops on the cast periphery for the positive location of special trays: one anteriorly and one each on the left and right buccal sulcus regions. The cast was then duplicated using a reversible hydrocolloid impression material, to provide three duplicate casts.

A silicone impression of the first cast was recorded using a 2mm spaced custom tray. A silver-plated cast was selected as the master cast material as it has been shown to exhibit moderately high strength, adequate hardness, excellent abrasion resistance and is non-absorbent[22,23,24]. Silver-plated casts have been shown to exhibit the highest hardness, least surface roughness and the least material loss in two body abrasion testing[25].

The second and third casts were overlaid with even thicknesses of 2mm and 4mm of pink sheet wax respectively, and this was confirmed using a Williams periodontal probe. These layers of wax were used to act as spacing during custom impression tray construction. Custom trays were used throughout the study as they have been shown to produce casts which are more accurate and consistent in reproduction[26]. An alginate impression was recorded of each spaced cast, taking care to include the seating notches in the periphery of the casts. These alginate impressions were poured up in a Type IV dental stone (GC Fujirock Type IV Dental Stone, GC UNITED KINGDOM Ltd.), using the manufacturers recommended powder to liquid ratio and a vacuum mixer. The impressions of the spaced casts were poured up on a vibrating table, and allowed to set for twenty-four hours. Customised trays were constructed by manipulating visible light cured acrylic resin blank sheets over each of the casts. Care was taken to include the three peripheral notches into the custom trays so as to standardise tray design and seating.

The tray material was cured in a light box for 10 minutes, as recommended by the manufacturer. Excess wax was removed from the fit surface of the impression trays prior to curing for a further ten minutes. The trays were then each seated on their appropriate casts, and a two millimetre space was prepared between the tray edges and the cast, to allow for venting of any excess impression material, and correct seating of the trays. The anterior and lateral stops were not modified.

Five impression trays with two millimetres of spacing and five impression trays with four millimetres of spacing were produced. Five alginate impressions of the silver-plated cast were made – one in each of the 4mm-spaced custom acrylic trays. Similarly, five silicone impressions were recorded in 2mm-spaced customised trays. Alginate mixing was standardised by using a semi-automatic alginate mixing device (Dux

Dental Alginator II, No. 25231). Variations in alginate mixing technique have been reported to have notable effects on setting time, resultant alginate and material mechanical properties[22]. Appropriate tray adhesives were used in all cases, to increase the bond strength between impression materials and the tray[23] and to reduce the likelihood of material separation[24]. The impressions were poured up in a type IV dental stone to provide ten casts. The base of each cast was trimmed and assessed using a paralleling device to ensure that the occlusal plane was parallel to the horizontal axis and comparable between all of the casts. The silver-plated master cast was profiled three times, and each of the ten resultant casts were profiled using a diamond probe on a Renishaw Incise contact co-ordinate measuring machine, to yield thirteen highly accurate and reproducible digitised topographical scans.

Fifteen landmarks were identified on the casts which coincided with natural anatomical features and those created as part of the denture design as shown in Figure 1.

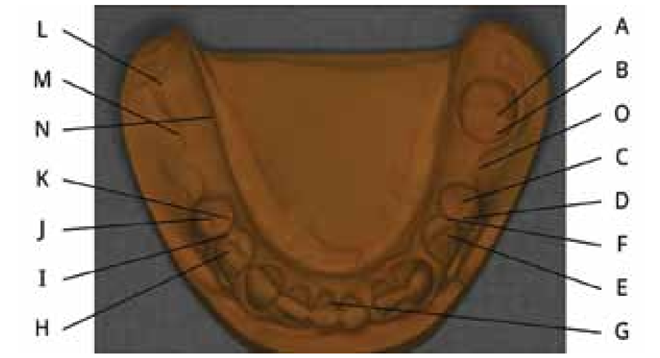


Figure 1. Photograph to show the points at which measurements were made following superposition

The digitised scans were superposed using the Cloud Software, developed by University College London. This software was used to quantify the differences between surfaces between the scans of all of the different casts in all combinations at each of the fifteen landmarks. For all combinations of cast superposition, the greatest difference between scans at each site was recorded. Within the limitations of this study, this revealed data pertaining to the accuracy of reproducibility of alginate and silicone as impression materials, as well as quantification of the dimensional differences between surfaces between casts derived from alginate and silicone impressions.

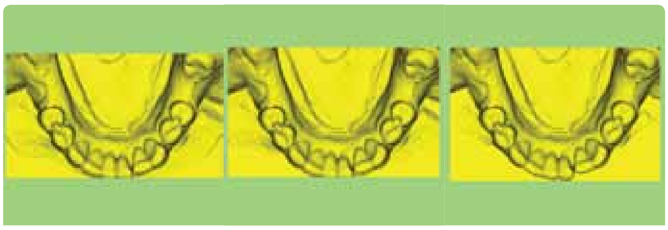


Figure 2. Scans resulting from profiling of the silver-plated master cast

The three scans of the master silver-plated cast were labelled M1, M2 and M3. The alginate scans were labelled A1, A2, A3, A4 and A5, and the silicone scans were labelled S1, S2, S3, S4 and S5.

A pilot study was designed and carried out to investigate the potential for damage caused to casts by scanning with a contact co-ordinate measuring machine. We examined the various surfaces of a type IV dental stone sample, before and after profiling, using a laser confocal microscope. The pilot study revealed that the contact co-ordinate measuring machine used resulted in no damage to the surface of a type IV dental stone sample, when viewed by a laser confocal microscope at x40 magnification.

RESULTS

As the acquired data was non-parametric in distribution, median values for data sets have been described. Although mean values have been listed, they have not been discussed. It was considered that irrespective of whether the values were positive or negative, the actual numerical value was of greater significance, as it was indicative of the degree of difference between surfaces.

The differences between scanned surfaces of each of the silicone, alginate and the master casts were recorded in Microsoft Excel spreadsheets, and these raw data were manipulated to create a table for use in the SPSS statistical analysis software.

The following results tables show the distances found between the surfaces of superposed scans at the different sites, A-O, as indicated in Figure 1.

The results of this analysis are presented on the following pages.

DIFFERENCES BETWEEN SURFACES BETWEEN THREE SILVER-PLATED MASTER CAST SCANS

Digitisation:

Three scans were made of the same master-cast using a Renishaw Incise contact co-ordinate measuring machine with a stylus with a 1mm diameter ball tip. The scanning interval was 0.1mm and scanning speed was 600mm/min. These scans are demonstrated in Figure 2.

An analysis of the superposed scans demonstrating any variation between the casts is demonstrated in Figure 3.

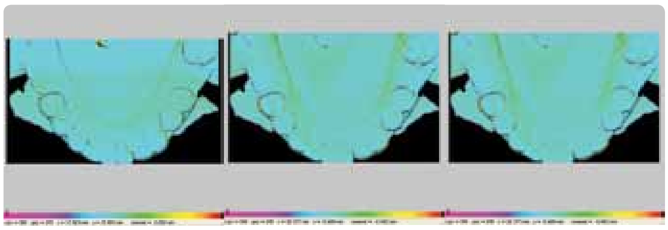


Figure 3. Showing superposition analysis results for the silver-plated metal cast.

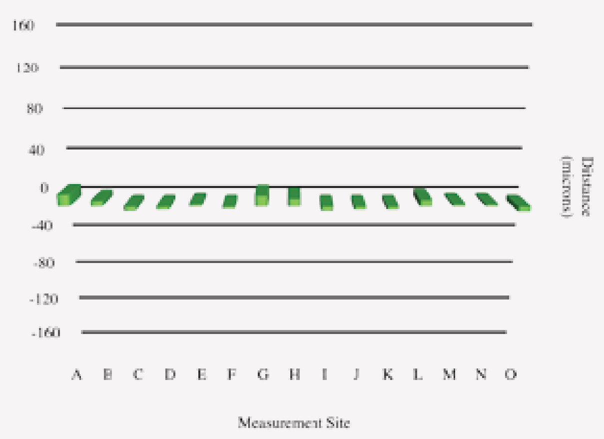
Table 1

Showing Differences Between Surfaces Between Three Silver-Plated Master Cast Scans at Pre-Selected Measurement Sites (microns)

Point	A	B	C	D	E	F
Mean	12	5	- 4	- 2	5	- 2
Median	11	5	- 4	- 3	2	- 2
Minimum	-0.0	4	- 6	- 50	-5	- 6
Maximum	20	6	- 2	1	17	1
Range	20	10	4	51	22	7

Point	G	H	I	J	K	L
Mean	10	7	- 2	3	- 1	6
Median	10	7	- 4	- 3	- 3	6
Minimum	0.0	5	0.0	- 5	- 3	4
Maximum	0.0	8	0.0	17	2	9
Range	0.0	3	0.0	22	5	13

Point	M	N	O
Mean	69	0.0	7.5
Median	4.5	11.5	6
Minimum	-6	52	-24
Maximum	35	230	38
Range	41	282	62



Graph 1. Graph showing the difference between surfaces between silver-plated master cast samples at pre-selected sites

DIFFERENCES BETWEEN SURFACES BETWEEN THREE SILVER-PLATED MASTER CAST SCANS

The range of the data gave some indication of the error regarding reproducibility of superposition. It was thought that three scans of the same cast should provide near ideal superposition, and the differences between surfaces ought to be negligible. The scans shown in Figure 3 indicated that in all combinations of scan superposition, 99% of areas had a difference between surfaces of <7 μm. Superposition involving the third scan of the master cast found that 99% of areas had a difference between surfaces of <5 μm. This was indicative of a high degree of reproducibility of not only the contact coordinate measuring machine, but also of the high accuracy of the Cloud software.

The data indicated that for all points the median difference between surfaces ranged from zero to 11 microns. The greatest differences between surfaces were found at sites A and G, and were found to be 11 and 10 microns respectively. Sites A and G represented the edge of the occlusal rest seat on the lower left second molar and the cingulum rest seat on the lower right central incisor. Whilst these values for differences between surfaces were the largest in the data set, it was felt that the actual values were very small, especially in comparison with the subsequent data sets.

Site D exhibited a range of 51 microns and this was unusual, and not in line with the other range data. It is possible that it was an outlier. With a median difference in surfaces of 3 microns at this site it would be reasonable to doubt the validity of this value. At site D there was a mesial rest seat in the mesially tilted lower left second molar, and this area was associated with an undercut. The vast majority of sites showed a median difference in surfaces of between 0 and 7 microns, the overwhelming majority being less than 4 microns. Graph 1 in the results section also reflects the very small differences between surfaces between the different scans of the same master cast.

This data indicated that the reproducibility of the method was very good, and highly accurate data was yielded at the vast majority of sites, where the range of the data was less than 6 microns. This data also indicated that measurement sites A and G showed the greatest difference in surfaces, and consideration of these differences would be helpful when analysing the data of the subsequent groups at these two sites in particular.

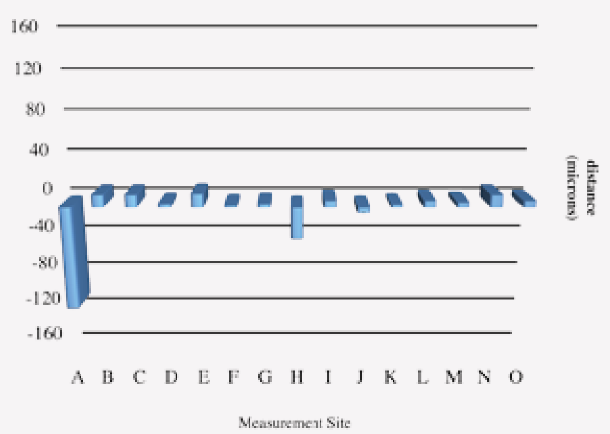
Table 2

Showing the Differences Between Surfaces Within the Silicone Sample Group at Pre-Selected Measurement Sites (mm)

Point	A	B	C	D	E	F
Mean	- 67.4	3.3	5.2	3	21.5	1.9
Median	- 101	11.5	11.5	3	12.5	1.5
Minimum	-140	-44	-9	-5	29	5
Maximum	60	44	45	13	-163	11
Range	20	88	54	18	-192	6

Point	G	H	I	J	K	L
Mean	3.4	19	21.6	5.4	-12	7
Median	3	-30.5	6	-5	2.5	6
Minimum	-20	-700	-20	-35	-170	-39
Maximum	30	95	250	61	229	19
Range	50	795	270	96	399	58

Point	M	N	O
Mean	69	0.0	7.5
Median	4.5	11.5	6
Minimum	-6	-52	-24
Maximum	35	230	38
Range	41	282	62



Graph 2. Graph showing the difference between surfaces between silicone samples at pre-selected sites

DIFFERENCES BETWEEN SURFACES OF SCANS OF SILICONE-DERIVED CASTS

The difference between surfaces of casts formed from silicone impressions gives an indication of the variability and reproducibility of the material. It could also be considered as the standard to which alginate can be compared.

The range of medians for difference between surfaces for silicones was considerably larger than that for the master cast group, as one would expect. Site A showed the largest difference between surfaces with a value of 101 microns, and a range of 200 microns. All other sites had differences between surfaces of between 1.5 and 30.5 microns, which is indicative of an extremely high level of accuracy of reproduction and subsequent superposition. However the data revealed a large range of values at multiple sites, including 200 microns at site A, 192 microns at site E, 795 microns at site H, 270 microns at site I, 399 microns at site K and 282 microns at site N. Whilst the small difference in surfaces was positive, it was surprising to see such a large range of data for each site. However, the mean and median data values for each site are supportive of the high reproducibility of this material. Graph 2 in the results section also reflects the relatively small variability between differences of surfaces across the measurement sites, and highlights site A and H as those with the greatest disparity. In comparison to the master cast data, site A is the most notable difference between surfaces in both groups.

The data reflects that the silicone group is capable of producing highly reproducible casts, with the vast majority of sample surfaces having differences of less than 12.5 microns.

Table 3

Showing the Differences Between Surfaces Within the Alginate Sample Group at Pre-Selected Measurement Sites (mm)

Point	A	B	C	D	E	F
Mean	- 39	- 22	64	32	89	36
Median	- 130	- 5	74	18	72	41
Minimum	- 240	- 160	- 90	- 50	59	- 15
Maximum	260	53	172	148	184	77
Range	500	213	262	198	125	92

Point	G	H	I	J	K	L
Mean	14.8	58.4	18.9	73.6	24.4	-2
Median	- 33.5	52.5	31.5	136.5	22	20
Minimum	- 150	- 37	- 50	- 138	- 195	- 69
Maximum	190	166	60	197	170	118
Range	340	203	110	335	365	187

Point	M	N	O
Mean	32	- 18	- 6
Median	41	- 9	- 11
Minimum	- 63	- 71	- 50
Maximum	80	73	36
Range	143	144	86

Graph 3. Graph showing the difference between surfaces between alginate samples at pre-selected sites

DIFFERENCES BETWEEN SURFACES OF SCANS OF ALGINATE-DERIVED CASTS

The difference between surfaces using superposition within the alginate group was investigated to gain an indication of the variability between resultant casts within this group. It also helped to give an idea of the reproducibility of impressions within the group.

The alginate group showed a larger range of differences between surfaces when compared to the silicone group. The largest differences between surfaces were noted at sites A and J, and were 130 microns and 136.5 microns respectively. This large difference is comparable to the silicone group at Site A (101 microns), but not at Site J (5 microns) The clinical significance of these differences between surfaces between the alginate and silicone groups lies in the fact that the differences range from 5 to 74 microns, excluding the 130 and 36.5 micrometre sites. Some consideration must be given to whether a difference between surfaces of this magnitude is significant clinically and when superposition data of the two groups is considered.

The range of the data in the alginate group is considerably larger than either the master cast or the silicone groups, with the range of data at various sites being between 86 and 365 microns. In the alginate group, thirteen of the fifteen measurement sites had ranges of over 110 microns, five of these being over 200 microns and two of these being over 300 microns. These large ranges tend to indicate that the alginate group may have greater variability in accuracy of reproducibility, and while the mean and median data are complimentary of the alginate group, the variability of reproduction is less favourable.

Graph 3 in the results section reflects the data, showing that while sites A and J show the greatest difference between surfaces, there are also a large number of additional sites with differences between surfaces which are greater than those in the silicone and master cast group results.

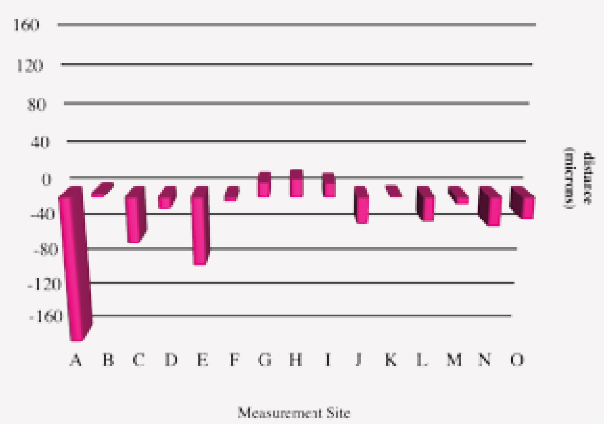
Table 4

Showing the Differences Between Surfaces Between Master and Silicone Derived Cast Samples at Pre-selected Measurement Sites (mm)

Point	A	B	C	D	E	F
Mean	- 113	1	- 68	- 14	- 47	- 6
Median	- 154	4	- 47	- 11	- 70	- 4
Minimum	- 190	- 44	- 132	- 36	- 82	- 24
Maximum	- 20	55	- 19	5	15	12
Range	170	99	113	41	97	36

Point	G	H	I	J	K	L
Mean	27	- 12	- 10	35	6	- 23
Median	15	18	14	- 27	1	- 25
Minimum	10	- 139	- 50	- 54	- 10	- 28
Maximum	80	37	20	150	33	- 18
Range	70	176	70	204	43	10

Point	M	N	O
Mean	- 6	- 28	- 13
Median	- 7	- 30	- 22
Minimum	- 13	- 50	- 30
Maximum	3	- 5	11
Range	16	45	41



Graph 4. Graph showing the difference between surfaces between master and silicone casts at pre-selected sites

DIFFERENCES BETWEEN SURFACES OF SCANS OF THE SILVER-PLATED MASTER CAST AND SILICONE IMPRESSION-DERIVED CASTS

The data showed that the differences between surfaces were small with site A showing the largest difference of 154 microns. The remainder of the sites were between 1 and 47 microns, the vast majority of the distances being less than 30 microns. This implies that silicone is a very good material for recording impressions and thus casts which are highly accurate in comparison to the master cast. This would be a very faithful material for cobalt-chromium framework construction.

The range of the data was small suggesting a high degree of reproducibility. The highest ranges were found associated with sites C, H and J, which had ranges of 113, 176 and 204 microns respectively. The vast majority of other sites had data ranges from 10 to 99 microns, seven of which were less than 45 microns, supporting the recording of a high accuracy of detail when taking impressions.

Graph 4 in the results section reflected the good superposition between the two groups, and serves as a point of comparison for the master cast to alginate comparison data. The graph highlights sites A and E as those with the largest difference between surfaces with magnitudes of 154 and 70 microns respectively. The majority of other sites showed significantly smaller differences between surfaces.

STATISTICAL ANALYSIS OF THE DATA

The distribution of the acquired data was not found to be normal so a non-parametric statistical significance test (Mann-Whitney U Test) was used. Statistically significant figures in the table are highlighted in yellow.

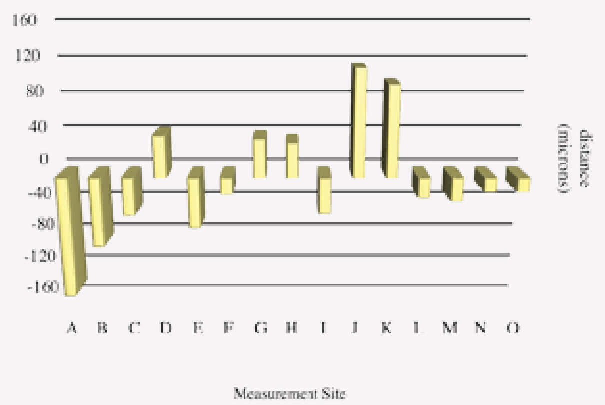
Table 5

Showing the Differences Between Surfaces Between Master and Alginate Cast Samples at Pre-Selected Measurement Sites (mm)

Point	A	B	C	D	E	F
Mean	- 63	- 41	14	26	- 8	- 10
Median	- 136	- 78	-42	46	- 56	- 18
Minimum	-350	- 84	- 160	- 77	- 61	- 29
Maximum	240	39	206	96	93	28
Range	590	123	366	173	154	57

Point	G	H	I	J	K	L
Mean	38	38	- 28	30	11	- 20
Median	42	38	- 40	117	100	- 22
Minimum	- 210	- 133	- 70	- 158	- 73	- 88
Maximum	170	197	20	179	94	36
Range	380	330	90	337	167	124

Point	M	N	O
Mean	- 18	- 13	- 7
Median	- 26	- 15	- 15
Minimum	- 73	- 69	- 22
Maximum	90	30	29
Range	163	99	51



Graph 5. Graph showing the difference between surfaces between master and alginate cast samples at pre-selected measurement sites

DIFFERENCES BETWEEN SURFACES OF SCANS OF THE SILVER-PLATED MASTER CAST AND ALGINATE IMPRESSION-DERIVED CASTS

The data showed a larger variation of surfaces in comparison to the silicone group at a greater number of sites. Sites A, J and K showed the largest differences between surfaces, measuring 136, 117 and 100 microns respectively. Site A is comparable to the silicone/master cast group, which had a magnitude of 154 microns at this site.

The remaining twelve sites showed differences of between 18 and 78 microns, where ten of the sites were 40 microns or less. This finding is in reasonably close comparison with the silicone/master cast group. Although the silicone/master cast group had only one site with a notably large difference between surfaces, the majority of sites showed differences of less than 47 microns. In consideration of this, it is interesting to consider the limit of difference between surfaces beyond which the construction and clinical fit of a cobalt-chromium framework would become ineffective or impossible. This may be investigated and quantified by constructing cobalt-chromium frameworks with inherent errors of known magnitude, and accuracy of fit can be then be assessed. In this way, a relationship could be identified as to what degree of construction error is acceptable while still allowing a cobalt-chromium framework to seat properly and fit.

The range of the data was considerably larger than that of the silicone/master cast group. Large data ranges were found for all sites except F, I, N and O. The range of the ranges was between 51 and 590 microns, and this is in considerable disparity to the silicone group. Although only site A had a range of 590 microns, four sites had ranges of 300 to 400 microns in magnitude, whilst the remaining ten sites had ranges of less than 175 microns. This reflects the greater possibility of variability when using alginate, compared to silicones. This may have been the result of the inherent properties of the materials or the potential variation associated with mixing alginates, and the more predictable mixing and dispensing of silicones.

Graph 5 in the results section reflects the large differences between surfaces at sites A, J and K, and whilst it is different in comparison to the silicone/master cast graph, it is apparent that the magnitudes of differences are not dissimilar. Thus it would appear that both materials have the ability to accurately reproduce the master cast with a comparable degree of superposition. Again, this raises the question as to the degree of accuracy which is necessary for framework construction.

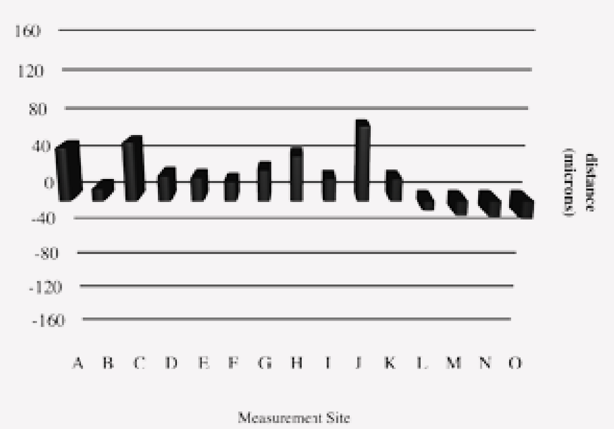
Table 6

Showing the Differences Between Surfaces Between Silicone and Alginate Cast Samples at Pre-Selected Measurement Sites (mm)

Point	A	B	C	D	E	F
Mean	19	11	53	21	8	25
Median	53	12	58	25	23	19
Minimum	-190	- 74	- 69	- 97	-140	- 54
Maximum	190	93	144	120	141	73
Range	380	167	213	217	281	127

Point	G	H	I	J	K	L
Mean	44	27	19	59	17	- 8
Median	31	45	22	74	22	- 9
Minimum	- 120	- 176	- 150	- 176	- 165	- 93
Maximum	190	144	170	183	151	99
Range	310	320	320	359	316	192

Point	M	N	O
Mean	- 5	- 16	- 1
Median	- 14	- 15	- 18
Minimum	- 72	- 90	- 60
Maximum	117	116	52
Range	189	206	112



Graph 6. Graph showing the difference between surfaces between silicone and alginate cast samples at pre-selected sites

DIFFERENCES BETWEEN SURFACES OF SCANS OF THE SILVER-PLATED MASTER CAST AND ALGINATE IMPRESSION-DERIVED CASTS

In comparing the differences between surfaces of casts derived from alginate and silicone, the magnitudes of differences are significant indicators of alginate's ability to produce casts of comparable accuracy to silicone.

In all data sets thus far, Site A has shown the greatest difference between surfaces. Following superposition of the alginate and silicone scan data, it is apparent, that their abilities and limitations lend them to producing extremely similar casts, with a high degree of accuracy. In consideration of the median values, each site showed a difference between surfaces of between 12 and 74 microns. Site J showed a difference between surfaces of 74 microns, whilst sites A, C and H showed differences of 53, 58 and 45 microns respectively. All other sites showed differences of less than approximately 30 microns. Ten of the fifteen sites showed differences between surfaces of less than 25 microns.

As was likely to be expected, this data set showed the largest ranges. The ranges for data at all sites varied between 112 and 380 microns. This large range reflects the large degree of variability within the data sets, but in spite of this the median and mean differences between surfaces are extremely small.

Graph 6 in the results section reflects that sites A, C and J showed the largest differences between surfaces, but for the most part, the majority of sites showed differences of less than 30 microns.

Table 8

Table showing the Results of Statistical Analysis of the Comparison of Differences Between Surfaces of Pairs Between Groups of Only Alginate and Groups of Only Silicone Samples

Point	A	B	C	D	E	F
Mann-Whitney U	48.5	42	31	21.5	9	20
Wilcoxon W	103.5	97	86	76.5	64	75
Z Value	- 0.113	- 0.605	-1.44	- 2.16	- 3.10	- 2.27
P Value	0.912	0.579	0.165	0.029	0.001	0.023

Point	G	H	I	J	K	L
Mann-Whitney U	30.5	13	36	30	43	45
Wilcoxon W	85.5	68	91	85	98	100
Z Value	- 1.48	- 2.79	- 1.06	- 1.51	- 0.529	- 0.378
P Value	0.143	0.004	0.315	0.143	0.631	0.739

Point	M	N	O
Mann- Whitney U	16	28	32.5
Wilcoxon W	71	83	97.5
Z Value	- 2.57	- 1.66	- 1.32
P Value	0.009	0.105	0.190

DISCUSSION

The data provided quantifiable differences between scans of surfaces of casts derived from alginate, casts derived from silicone and a silver-plated metal cast at various sites. In most cases in research, tolerance limits or guidelines are available for the point beyond which fit of a medical device is not acceptable. Unfortunately, within the realms of removable partial prostheses, no such quantifiable limit exists, and this may be due to the adaptability of oral tissues and the resilience of the oral soft tissues and periodontal ligament investing the teeth. A Mann Whitney U non-parametric statistical analysis was used to compare pairs of sites, using alginate and silicone. P values of <0.05 were found for one fifth of the sites, these being D, E, F, H and M. These represent the floors of occlusal rest seats in the lower right first and second pre-molars, the edge of the occlusal rest seat in the lower right first premolar and on the mid-crestal portion of the free-end saddle in the lower right quadrant, which are statistically significant differences. It is interesting to note that in the vast majority of comparisons, especially involving alginate, site A showed the largest difference between surfaces. This tooth was mesially tilted and had a rather shallow rest seat preparation. In light of the mesial tilt, an undercut was present at the mesial aspect of the tooth, and the large differences in surfaces may have resulted from impression material distortion due to firstly a lack of bulk of material being present in this area, and secondly due to the potential distortion following withdrawal of the impression from the undercut. In the vast majority of superpositions, sites A, E and H, which represent the edge of the mesial rest seat in the lower left second molar, the floor of the rest seat in the lower left first pre-molar and the edge of the rest seat in the lower right first pre-molar, showed the greatest data ranges. This tends to indicate that rest seat preparations are significant features which have an impact on the type of impression material used. It would be interesting to investigate the effect of topographical, dimensional and location variations of rest seats and their impacts on recording of master impressions with the two impression materials used in this investigation. However, it is unclear why some of the rest seats in this study were recorded with very small differences in surfaces, while others such as at sites A, E and H tend to show comparatively large differences. This may have resulted from the explorative limitations of the scanning probe. It appears that within the confines of this study, relatively small differences in surfaces were noted for the edentulous regions, and one would propose that this is due to the simple topography at those areas, which are in stark contrast to the complex surface forms presented by teeth.

In the absence of accepted guidelines for the degree of accuracy needed for a cobalt-chromium framework to fit well, it is difficult to make absolute judgments and recommendations for the use of alginates as impression materials in this clinical scenario. However, in consideration of factors such as the resilience of the periodontal ligament and individual tooth morphology and position, the material with the highest accuracy is not necessarily the only and best option. Inaccuracies and variables during impression recording cannot always be compensated for, and yet prostheses still fit. Mucosal tissue displacement can be in the order of 2 mm while the resilience of the periodontal ligament can allow for movements in the order of 100 microns[30]. In light of the findings of this investigation, differences in the order of 100 microns were noted, but none of the median values for differences between surfaces when superposing alginate with silicone scans reached this level, and thus it would appear that irreversible hydrocolloid may be a viable alternative to addition-cured polyvinylsiloxane impression materials, when the impressions are used within the manufacturers' recommended guidelines, and they are poured up soon after recording the impression. The data obtained from the different groups investigated by superposition also tend to indicate that not all dental arches may be suitable for recording master impressions in irreversible hydrocolloid. Deep undercuts, such as those where a tooth may have tilted mesially may be inappropriate scenarios for the use of alginate. Site A in our investigation is very close to such an area, and the large median values obtained in this area may be indicative of a limitation of the use of alginates. Jørgensen (1978) has made note of this limitation of alginate[13], with reference to deep soft tissue undercuts. It is also wise to ensure that in recording impressions with alginate, sufficient bulk of alginate is present to prevent material distortion, inaccuracy and the risk of tearing.

An enquiry into the use of alginates versus silicones is necessary for a number of reasons. Firstly, as the most commonly-used impression material today[2,3,4] the efficacy of alginates within the confines of their limitations is apparent. They are widely-used due to their cost-benefit ratio, their ease of handling, good shelf life, bio-compatibility and their versatility of use. Their hydrophilic nature confers great advantage in comparison to the silicone family of materials, which results in a more forgiving material. Secondly, alginate impression materials are cheap, particularly in comparison to the majority of available silicone impression materials. A 500 gram pack of alginate material was found to cost in the region of £5.20. This was based on a package of twelve packs costing £62.40. The manufacturer recommends two scoops, equivalent to 18 grams for each impression. There is a potential of twenty-seven impressions achievable from a 500 gram pack, which equates to nineteen pence per impression. In comparison to this, a medium bodied addition-cured polyvinylsiloxane impression material was found to cost £30 for two 50ml cartridges and mixing tips. With approximately one cartridge yielding two impressions, the cost was found to be in the region of £7.50 for one impression. Whilst a cost ratio of 1:40 is very large, the significant benefits associated with addition-cured silicones cannot be negated. The over-riding question is: do we need the advantages and, in particular, considerably greater accuracy afforded by silicone impression materials in the construction of cobalt-chromium framework dentures?

As is often the case, it is unlikely that there is a straightforward answer to this question, and clinical experience will tend to be the clinician's guide. However, cases involving large undercuts and the presence of tilted teeth may be justifiable scenarios for the use of addition-cured polyvinylsiloxane materials. Also, the hydrophobic tendencies of the silicone materials make their use in the potentially wet environment of the mouth, and more so in the hypersalivating patient, more challenging. The fourth factor in consideration of the two impression materials is that of pollution. The ease with which the two impression materials biodegrade are significant considerations, especially in light of the focus on today's 'green issues'. Irreversible hydrocolloids are formed using a number of metal ion salts, and alginic acid from renewable seaweed and water, whilst silicones are synthetically-produced organic polymers, often with very long half-lives. A comprehensive search of Medline and PubMed databases failed to reveal any half-life data for either of the two impression materials.

Irrespective of the financial and environmental considerations, establishment or rejection of the use of irreversible hydrocolloid as a master impression material for cobalt-chromium framework construction has still been a largely unanswered question.

The use of a contact co-ordinate measuring machine to produce digitised surface scans of casts, which were superposed to investigate dimensional differences is novel. The contact co-ordinate measuring machine does not damage the surface of Type IV dental stone, and therefore appears to be appropriate for this purpose. Furthermore superposing scans of casts appears to be an accurate method for comparing them.

Within the confines of this in vitro study, it would appear that irreversible hydrocolloid does not appear to be as accurate as silicone, but that for most areas, with the exception of undercuts, this is probably not clinically significant. It is recommended that further investigation and clinical studies are required to verify this.

CONCLUSIONS

In light of this investigation we have concluded that:

1. The contact co-ordinate measuring machine is capable of producing highly accurate digitised scans of dental casts, with a high degree of reproducibility, without damaging the surface of Type IV dental stone.
2. Within the confines of this *in vitro* investigation, it would appear that irreversible hydrocolloid impression materials are possible viable alternatives to addition-cured polyvinylsiloxane, in the construction of cobalt-chromium frameworks.
3. The difference between surfaces of silicone and alginate scans revealed median values of less than 75 microns differences, and mean value differences of less than 59 microns.
4. Future research is required to confirm these findings in *vivo*.

MANUFACTURERS DETAILS

- GC Fujirock Type IV Dental Stone; LOT Number 0610251. GC UNITED KINGDOM Ltd., 12-15, Coopers Court, Newport Pagnell, Bucks. MK16 8JS.
- Irreversible Hydrocolloid Impression Material – Zhermack Hydrogum, LOT Number 55286. Zhermack, 28 Arthurs Avenue, Harrogate, North Yorkshire, HG2 0EB.
- Irreversible Hydrocolloid Adhesive – Dentsply Detrey Adhesive, LOT 0608000462. Dentsply, Building 3, The Heights, Weybridge, Surrey KT13 ONY.
- Kerr Extrude Medium-Bodied Addition Cured Polyvinylsiloxane Impression Material. LOT number 28736B, Reference 6-2187. Kerr UK Ltd, 4 Flag Business Exchange, Vicarage Farm Road, Peterborough PE1 5TX
- Polyvinylsiloxane Adhesive - Kerr VPS Adhesive, LOT Number 60028. Kerr UK Ltd, 4 Flag Business Exchange, Vicarage Farm Road, Peterborough PE1 5TX.
- Renishaw Incise – Contact Co-Ordinate Measuring Machine. Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL12 8JR.
- Visible Light Cured Acrylic for Special Trays – VLC Acrylic Tray Wafers; Batch No 061477. Bracon Dental Laboratory, Bracon Limited, High Street, Etchingham, East Sussex, TN19 7AL.
- Reversible Hydrocolloid Impression Material – Dentsply Polyflex Duplicating Material; Batch No 060824-2. Dentsply, Building 3, The Heights, Weybridge, Surrey KT13 ONY.
- Dux Dental Alginator II, No. 25231 – Alginate Automixer. Dux Dental, Zonnebaan 14, 3542 EC Utrecht, The Netherlands.

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