J Indian Prosthodont Soc (Oct-Dec 2013) 13(4):428–438
DOI 10.1007/s13191-013-0255-9

ORIGINAL ARTICLE

A Comparative Evaluation of the Linear Dimensional Accuracy of Four Impression Techniques using Polyether Impression Material

Smita Sara Manoj · K. P. Cherian ·
Vidya Chitre · Meena Aras

Received: 16 January 2012 / Accepted: 13 January 2013 / Published online: 6 February 2013
© Indian Prosthodontic Society 2013

Abstract There is much discussion in the dental literature regarding the superiority of one impression technique over the other using addition silicone impression material. However, there is inadequate information available on the accuracy of different impression techniques using polyether. The purpose of this study was to assess the linear dimensional accuracy of four impression techniques using polyether on a laboratory model that simulates clinical practice. The impression material used was Impregum Soft™, 3 M ESPE and the four impression techniques used were (1) Monophase impression technique using medium body impression material. (2) One step double mix impression technique using heavy body and light body impression materials simultaneously. (3) Two step double mix impression technique using a cellophane spacer (heavy body material used as a preliminary impression to create a wash space with a cellophane spacer, followed by the use of light body material). (4) Matrix impression using a matrix of polyether occlusal registration material. The matrix is loaded with heavy body material followed by a pick-up impression in medium body material. For each technique, thirty impressions were made of a stainless steel master model that contained three complete crown abutment preparations, which were used as the positive control. Accuracy was assessed by measuring eight dimensions (mesiodistal, faciolingual and inter-abutment) on stone dies poured from impressions of the master model. A two-tailed *t* test was carried out to test the significance in difference of the distances between the master model and the stone models. One way analysis of variance (ANOVA) was used for multiple group comparison followed by the Bonferroni's test for pair wise comparison. The accuracy was tested at $\alpha = 0.05$. In general, polyether impression material produced stone dies that were smaller except for the dies produced from the one step double mix impression technique. The ANOVA revealed a highly significant difference for each dimension measured (except for the inter-abutment distance between the first and the second die) between any two groups of stone models obtained from the four impression techniques. Pair wise comparison for each measurement did not reveal any significant difference (except for the faciolingual distance of the third die) between the casts produced using the two step double mix impression technique and the matrix impression system. The two step double mix impression technique produced stone dies that showed the least dimensional variation. During fabrication of a cast restoration, laboratory procedures should not only compensate for the cement thickness, but also for the increase or decrease in die dimensions.

Keywords Dimensional accuracy · Impression material · Polyether · Impression technique · Impregum soft · Monophase · One step double mix · Two step double mix · Matrix

Introduction

Polyether impression materials are gaining popularity because of their physical properties, dimensional stability and ability to reproduce a highly accurate replica of the

S. S. Manoj (✉) · K. P. Cherian
Department of Prosthodontics, Azeezia College of Dental Science and Research Centre, Diamond Hills, Meeyyanoor, Kollam, Kerala, India
e-mail: drsmitamanoj@yahoo.co.in

V. Chitre · M. Aras
Department of Prosthodontics, Goa Dental College and Hospital, Santa Cruz, Goa, India

oral structures [1–4]. It was first introduced in dentistry in the late 1970s. Due to its hydrophilic nature, it forms a low contact angle with gypsum and hence is easy to pour [5–7]. Its high degree of wettability and absence of volatile by products contributes to better surface detail reproduction [2, 8] and good dimensional stability [2]. Stiffness of set polyether is advantageous when making impressions for implant supported prosthesis for an accurate repositioning of impression transfer copings and in the double arch impression to ensure tray rigidity and reduce the possibility of distortion [9]. However, stiffness can contribute to difficulty in impression removal from areas of tissue undercuts, and the retrieval of casts from the impression with resultant die breakage [10]. Another version of polyether impression material designated as ‘soft’ was developed with a goal of overcoming the stiffness of polyether for achieving ideal handling and convenience [11, 12].

Polyether was initially available in a single regular viscosity. Though slight modification of the viscosity was possible with the use of a diluent, monophase impression technique was the most commonly used impression technique [13]. However, with the introduction of heavy and light bodied systems, the use of one/two—step multiple mix techniques became popular. A fourth impression technique, the matrix impression technique for the effective management of the sulcular environment was developed by Livaditis[14, 15]. This technique requires a series of three impression procedures using three viscosities of impression material and the material of choice was polyether due to its high viscosity and necessary elasticity.

There is much discussion in the dental literature regarding the effect of various impression techniques on the accurate fit of cast restorations. Certain authors report that impression techniques do not affect accuracy, whereas others claim that impression materials have improved to such an extent that accuracy may be controlled more with technique than by the material itself [2, 16, 17]. Various authors have reported on the superiority of one impression technique over the other using addition silicone impression materials [8, 16–21]. However, there is inadequate information available on the accuracy of different impression techniques using polyether.

The purpose of this study was to compare the linear dimensional accuracy of stone models obtained from the polyether impression of a metal master model using the four impression techniques, namely, monophase, one step double mix, two step double mix and the matrix impression technique in order to identify the impression technique that displays the maximum linear dimensional accuracy. A new version of polyether impression material (Impregum Soft^{TM}, 3 M ESPE, Seefeld; Germany) available in three consistencies (heavy body, medium body and light body) was used for the study. Thus, the research hypothesis was that no difference in dimensional accuracy existed between the master model and the stone models that were obtained from the four different impression techniques.

Materials and Methods

A metal master model with three fixed dental prosthesis (FDP) abutment preparations was fabricated, by first fabricating three individual dies. Each die (Fig. 1a) simulated a clinical crown preparation with an occluso–gingival length of 9 mm and a taper of 10^{o}. The finish line was a 1 mm wide 90° shoulder to simulate the preparation for an all ceramic crown. Cross grooves were provided on the occlusal surfaces and a vertical groove was inscribed on the labial surface to serve as reference points for making measurements. The three dies were then welded onto a horizontal metal platform measuring 85 × 30 × 10 mm (length × width × height). A distance of 11 mm was maintained between the dies at the occlusal level. Two holes of 5 mm diameter were drilled on either side of the horizontal metal platform for proper orientation of the perforated metal tray (Fig. 1b, c).

A rigid metallic perforated tray was fabricated with a space of 4 mm for the impression material and perforations of 2 mm diameter for mechanical retention. Two vertical extensions were provided on the tray such that they fitted onto the corresponding holes on the metal platform for proper tray orientation (Fig. 2a–c).

A split metal carrier with a space of 3 mm for the impression material was fabricated to serve as a carrier to form the matrix in the matrix impression technique. A horizontal metallic extension and a 4 mm diameter hole were provided on either side of the sectioned surface for proper orientation and retrieval of the split components (Fig. 2d, e).

All the metallic components were fabricated from mild steel and with the exception of the inner surface of the tray and carrier, were chrome plated to avoid rusting. An appropriate tray adhesive supplied by the manufacturer (3 M ESPE) was thinly and evenly applied over the inner surface of the tray and allowed to dry for 10 min before impression making. The impression material was mixed at room temperature (25 ± 2 °C) in standard proportions according to the manufacturer’s recommendations. For each technique, thirty impressions of the master model were made.

For group I, impressions were made using the one step/ monophase impression technique where medium body impression material (Impregum Soft^{TM}, 3 M ESPE) was hand mixed and used as the tray and syringe material.

For group II, impressions were made using the one step double mix impression technique where heavy body was

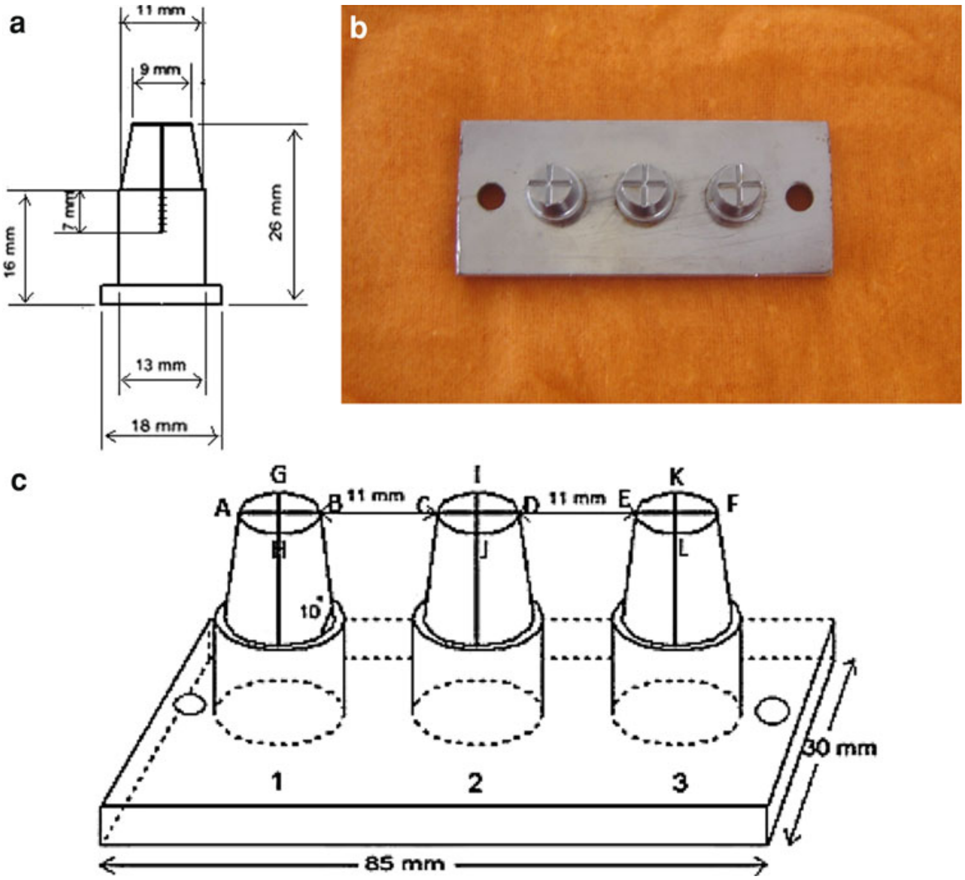

Fig. 1 **a** Schematic diagram of an individual die. **b** Metal master model showing the three dies welded onto a horizontal metal platform. **c** Schematic diagram of the metal master model displaying the mesiodistal measurements (*AB*, *CD*, *EF*), faciolingual measurements (*GH*, *IJ*, *KL*), and inter-abutment measurements (*BC*, *DE*)

used as the tray material and light body as the syringe material. Both were used simultaneously without any spacer.

For group III, impressions were made using the two step double mix impression technique with a cellophane spacer. l. Heavy body was used as the tray material and light body as the syringe material.

For group IV, impressions were made using the matrix impression system. Using the sectioned metal carrier, a matrix of polyether occlusal registration material (Ramitec$^{\text{TM}}$, 3 M ESPE) was made over the prepared abutments. On polymerizing, the matrix was separated from the carrier. The facial and palatal sides of the matrix were trimmed with a scalpel blade to maintain a thickness of 1–3 mm. The internal surface of the matrix in these areas was relieved by 0.25–0.75 mm. The internal occlusal surface was not trimmed since it had to serve as a vertical stop to prevent seating of the matrix beyond its original position. Heavy body impression material was syringed on the abutment preparations and also loaded into the matrix. The matrix was then placed on the master model. The perforated tray was immediately loaded with medium body impression material and seated over the matrix impression (Fig. 3a).

A working time of 2½ min for heavy and medium body and 3 min for the light body impression material was allowed as recommended by the manufacturer. All the impressions were allowed to set on the master model for twice the recommended setting time in the mouth (6 min for heavy and light body and 7 min for medium body). After removal from the master model, the impressions were rinsed under tap water for 10 s and air dried to simulate rinsing of blood and saliva after a clinical impression.

The impressions were stored in an airtight container containing silica gel for 30 min and then poured in type IV dental stone (die stone; modern materials; Heraeus Kulzer, USA). A ratio of 22 ml water: 100 g die stone was used as recommended by the manufacturer. The die stone was manually mixed with distilled water. A thin mix was initially painted on the impression surface using a camel hair brush. The remaining stone mix was vibrated into the impression and the stone models so formed were allowed to set for 1 h before they were separated from the impressions. A flat base was then made for each of the stone models using a custom made elastomeric base former. The stone models obtained from the impressions made using the monophase, one step double mix, two step double mix and the matrix impression techniques were designated as group I, group II, group III and group IV respectively (Fig. 3b).

The measurements on the master model as well as the stone models were made using a three dimensional coordinate

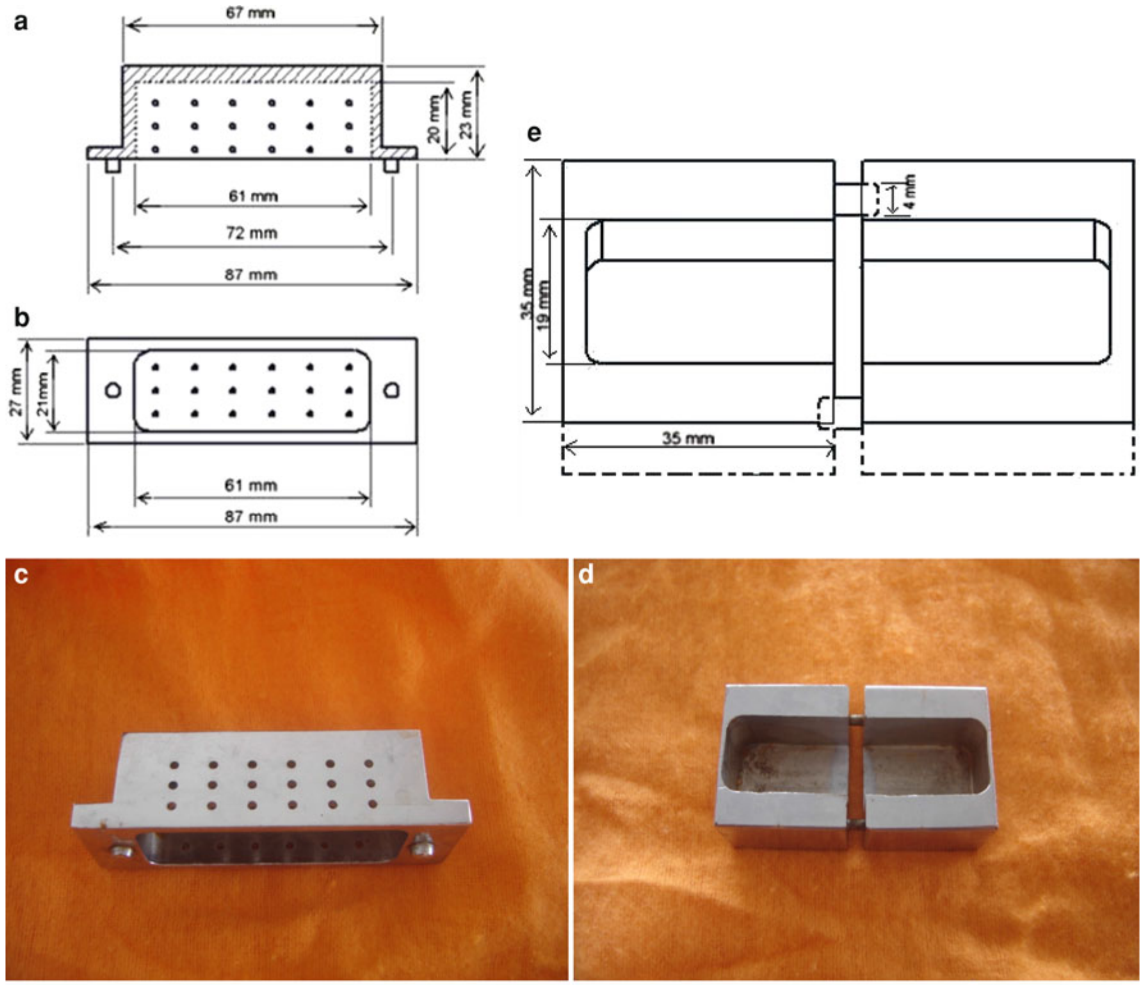

Fig. 2 **a, b** Schematic diagram of the perforated metal tray. **c** Perforated metal tray. **d** Metal carrier. **e** Schematic diagram of the split metal carrier

measuring machine (BH.V507, Mitutoyo, Japan) with a least count of 0.001 mm. The specimens were mounted on a jig to ensure that the occlusal surfaces of the three abutments were oriented in the horizontal plane (Fig. 3c). The measurements of inter-abutment, faciolingual and mesiodistal distances were made from the master and the stone models. The various distances measured were designated as follows (Fig. 1c).

Mesiodistal distances—AB (die 1), CD (die 2), EF (die 3)
Faciolingual distances—GH (die 1), IJ (die 2), KL (die 3)
Inter-abutment distances—BC (between die 1 and die 2), DE (between die 2 and die 3)

The mesiodistal, faciolingual and inter-abutment distances were measured 1 mm below the occlusal plane to avoid error using a 1 mm diameter probe. All the distances were calculated using 3D-Geopak-3 (version 5.42) computer software. Each distance for each specimen was measured three times and the mean value was calculated. Preliminary analysis of variance revealed no significant effect on the replicate measurements which allowed the use of a mean measurement for each specimen. The measurements on the master model and the stone models were tabulated and statistically analyzed.

The means for each distance location on the master model was used as the standard for comparison to the corresponding mean distances on the stone models obtained from the various impression techniques. The arithmetic mean, standard deviation, and percentage deviation of the stone models from the master model were calculated for each of the four groups (Tables 1, 2, 3, 4).

(a) The arithmetic mean was calculated as:

$$X = \frac{\Sigma Xi}{N}$$

Where $\sum$ = sum of, Xi = individual values, N = total number of observations.

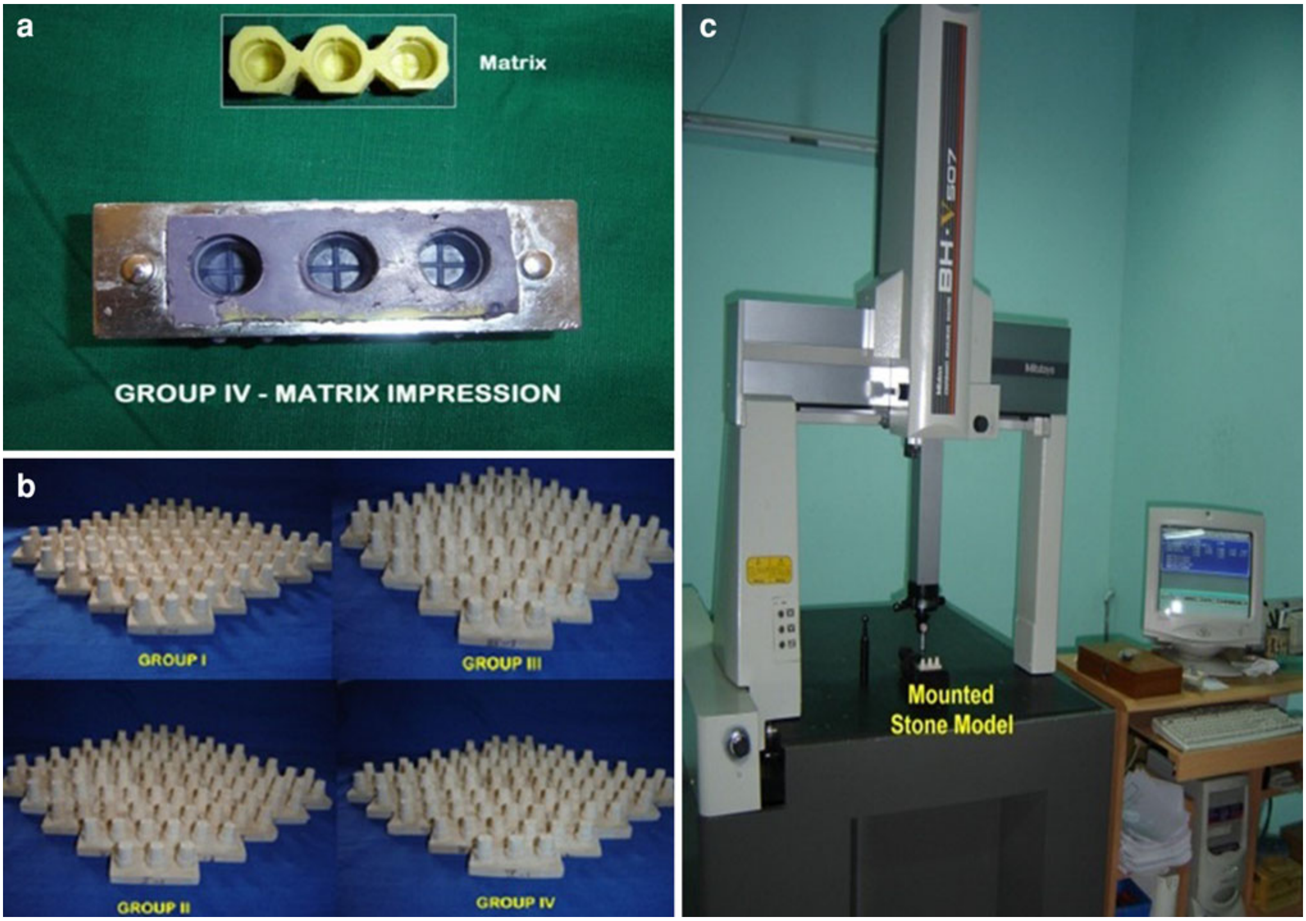

Fig. 3 **a** Matrix impression. **b** Stone model poured from the impressions of the master model. **c** 3D Co-ordinate measuring machine

(b) Standard deviation (SD) was calculated as follows:

$$\mathrm{SD} = \frac{\Sigma(\mathrm{Xi} - \mathrm{X})^2}{\mathrm{N} - 1}$$

Where $\sum$ = sum of, Xi = individual values, X = arithmetic mean, N = total number of observations.

(c) The percentage deviation of the stone models from the master model was calculated using the following formula;

$$\text{Percentage deviation } (\%\,\text{dev}) = \frac{(\text{msm} - \text{mmm})}{\text{mmm}} \times 100$$

Where msm = mean distance of the stone models, mmm = mean distance of the master model.

(d) The absolute change (dev) of the stone models from the master model was expressed as the difference in the means of the two samples.

(e) The degrees of freedom (df) were calculated as the total sample size minus one degree of freedom for each mean that was calculated.

A two-tailed *t* test was carried out to test the significance in difference of the distances between the master model and the stone models (Tables 1, 2, 3, 4). The two-tailed *t* test would document differences in either direction. One way analysis of variance (ANOVA) (Table 5) was used for multiple group comparison followed by the Bonferroni's test (Table 6) for pair wise comparison. The level of significance was determined by the *p* value. If the table value (*t*) is large, the *p* value will be small, because it is unlikely that a large *t* ratio will be obtained by chance alone. If the *p* value is 0.05 or less, it is customary to assume that there is a real difference.

Conceptually, the *p* value is the probability of being in error if the null hypothesis of no difference between the means is rejected and the alternative hypothesis of a true difference is accepted [22].

In this study, the *p* value and its implications are given as follows:

$p > 0.05$-Non significant values (NS)
$p < 0.05$-Significant values (S)
$p < 0.001$-Highly significant values (HS)

All statistical analysis was carried out using the Statistical Package for Social Scientists (SPSS) Version 11.5 computer software for Windows and Microsoft Office Excel 2003.

Table 1 Statistical analysis of the dimensional variation in stone models produced from the monophase impression technique as compared to the master model

	Master model (mm)	Group I (mm)	SD	% Dev	Dev (µm)	*t* Value	df	*p* Value
AB	9.556	9.502	0.014459	−0.565	−54	20.111690	29	0.0000 (HS)
CD	9.577	9.524	0.007042	−0.553	−53	40.529330	29	0.0000 (HS)
EF	9.350	9.293	0.006776	−0.610	−57	45.037260	29	0.0000 (HS)
GH	9.480	9.403	0.016749	−0.812	−77	24.863710	29	0.0000 (HS)
IJ	9.080	9.023	0.016327	−0.628	−57	18.800250	29	0.0000 (HS)
KL	9.178	9.083	0.014401	−1.035	−95	35.648530	29	0.0000 (HS)
BC	10.553	10.531	0.182415	−0.208	−22	0.659294	29	0.5149 (NS)
DE	10.481	10.478	0.011417	−0.029	−3	1.572148	29	0.1268 (NS)

The two-tailed *t* test revealed a highly significant difference for each measurement location between the master model and group I stone models except for the inter-abutment distances BC and DE

Table 2 Statistical analysis of the dimensional variation in stone models produced from the one step double mix impression technique as compared to the master model

	Master model (mm)	Group II (mm)	SD	% Dev	Dev (µm)	*t* Value	df	*p* Value
AB	9.556	9.624	0.182158	0.712	68	2.020087	29	0.0527 (NS)
CD	9.577	9.595	0.014619	0.188	18	6.630590	29	0.0000 (HS)
EF	9.350	9.386	0.012716	0.385	36	15.24573	29	0.0000 (HS)
GH	9.480	9.505	0.008606	0.263	25	15.85255	29	0.0000 (HS)
IJ	9.080	9.148	0.014412	0.749	68	25.40789	29	0.0000 (HS)
KL	9.178	9.200	0.012973	0.240	22	9.131708	29	0.0000 (HS)
BC	10.553	10.477	0.015646	−0.720	−76	26.04222	29	0.0000 (HS)
DE	10.481	10.410	0.016095	−0.677	−71	23.75459	29	0.0000 (HS)

The two-tailed *t* test revealed a highly significant difference for each measurement location between the master model and group II stone models except for the mesiodistal distances AB

Table 3 Statistical analysis of the dimensional variation in stone models produced by the two step double mix impression technique as compared to the master model

	Master model (mm)	Group III (mm)	SD	% Dev	Dev (µm)	*t* Value	df	*p* Value
AB	9.556	9.570	0.013298	0.147	14	5.534229	29	0.0000 (HS)
CD	9.577	9.6043	0.012447	0.282	27	11.537120	29	0.0000 (HS)
EF	9.350	9.367	0.013327	0.182	17	6.869382	29	0.0000 (HS)
GH	9.480	9.447	0.012468	−0.348	−33	14.397160	29	0.0000 (HS)
IJ	9.080	9.046	0.034866	−0.374	−34	5.251274	29	0.0000 (HS)
KL	9.178	9.164	0.011578	−0.153	−14	6.666571	29	0.0000 (HS)
BC	10.553	10.472	0.013009	−0.768	−81	33.668270	29	0.0000 (HS)
DE	10.481	10.400	0.014992	−0.773	−81	29.095050	29	0.0000 (HS)

The two-tailed *t* test revealed a highly significant difference for all the measurement locations between the master model and group III stone models

Results

For group I stone models (Table 1), the two-tailed *t* test revealed a highly significant difference for each measurement location between the master model and stone models except for inter-abutment distances BC and DE.

For group II stone models (Table 2), the two-tailed *t* test revealed a highly significant difference for each measurement location between the master model and stone models except for mesiodistal distance AB.

For group III stone models (Table 3), the two-tailed *t* test revealed a highly significant difference for all the measurement location between the master model and stone models.

For group IV stone models (Table 4), the two-tailed *t* test revealed a highly significant difference for each

Table 4 Statistical analysis of the dimensional variation in stone models produced by the matrix impression technique as compared to the master model

	Master model (mm)	Group IV (mm)	SD	% Dev	Dev (µm)	*t* Value	df	*p* Value
AB	9.556	9.499	0.054472	−0.596	−57	5.634877	29	0.0000 (HS)
CD	9.577	9.530	0.009445	−0.491	−47	26.986860	29	0.0000 (HS)
EF	9.350	9.330	0.014372	−0.214	−20	7.743785	29	0.0000 (HS)
GH	9.480	9.448	0.014472	−0.338	−32	12.031430	29	0.0000 (HS)
IJ	9.080	9.043	0.014301	−0.407	−37	13.932120	29	0.0000 (HS)
KL	9.178	9.143	0.012908	−0.381	−35	14.601160	29	0.0000 (HS)
BC	10.553	10.552	0.016266	−0.009	−1	0.441413	29	0.6622 (NS)
DE	10.481	10.458	0.012520	−0.219	−23	10.035660	29	0.0000 (HS)

The two-tailed *t* test revealed a highly significant difference for each measurement location between the master model and group IV stone models except for the inter-abutment distance BC

Table 5 One way ANOVA (Analysis Of Variance) for comparison of the distances between groups

	Total sum of squares	*F* ratio	df	*p* value
AB	0.377577611	4.814364606	3,36	0.0064 (HS)
CD	0.058172833	125.572611000	3,36	0.0000 (HS)
EF	0.056669278	102.921924300	3,36	0.0000 (HS)
GH	0.060368722	88.690676600	3,36	0.0000 (HS)
IJ	0.113924148	60.164225440	3,36	0.0000 (HS)
KL	0.079174778	128.470750600	3,36	0.0000 (HS)
BC	0.386347926	1.654365999	3,36	0.1941 (NS)
DE	0.049480370	65.019649290	3,36	0.0000 (HS)

The one way ANOVA revealed a highly significant difference for each distance (except inter-abutment distance BC) between any two groups of stone models obtained from the four impression techniques

measurement location between the master model and stone models except for the inter-abutment distance BC.

One way ANOVA (Analysis Of Variance) (Table 5) for comparison of the distances between groups revealed a highly significant difference for each distance location (except inter-abutment distance BC) between any two groups of stone models obtained from the four impression techniques.

Bonferroni's test (Table 6) for comparison of the mean distances between any two groups revealed

- Significant difference in distances (except inter-abutment distance BC) between group I and group II stone models.
- Significant difference in distances (except mesiodistal distance AB, and inter-abutment distance BC) between group I and group III stone models.
- Significant difference in mesiodistal distance EF, faciolingual distance GH, and inter-abutment distance DE between group I and group IV stone models.
- Significant difference in mesiodistal distance EF between group II and group III stone models.
- Significant difference in mesiodistal distance AB between group II and group IV stone models.
- Significant difference in faciolingual distance KL between group III and group IV stone models.

Discussion

Numerous studies [16–21, 23] have compared the accuracy of various impression techniques for addition silicone, but there are no similar studies comparing the accuracy of impression techniques for polyether impression material. Polyethers were usually available as a medium consistency material to be used with the monophase impression technique. They are now available in low, medium and heavy consistencies for application in the multiple mix impression techniques. This in vitro study was therefore designed to determine the impression technique that displays the maximum linear dimensional accuracy for polyether by assessing the linear dimensional change occurring along the horizontal axes of tooth preparation in a partial arch impression. The accuracy of the traditionally used monophase impression technique was also compared to the accuracy of the double mix and matrix impression techniques. Thus, the null hypothesis of no difference between the master model and stone models and the accuracy of the four impression techniques was tested at $\alpha = 0.05$.

The master model used was a highly polished machined steel die to facilitate better contact of the measuring probe of the three dimensional coordinate measuring machine. The perforations of the impression tray were kept parallel and perpendicular to the tensile axis for mechanical retention and tray adhesive provided the additional retention. Tray adhesive would minimize the marginal opening of a casting and also help to counteract the polymerization shrinkage of impression materials by redirecting this shrinkage towards the impression tray walls [9, 24–27]. A 4 mm space was provided for the impression material in

Table 6 Bonferroni's test for comparison of the mean distances between any two groups

	Group I vs. Group II		Group I vs. Group III		Group I vs. Group IV	
	t Value	*p* Value	*t* Value	*p* Value	*t* Value	*p* Value
AB	3.161750	0.003 (S)	1.748870	0.089 (NS)	0.077536	0.939 (NS)
CD	13.372420	0.000 (HS)	15.004730	0.000 (HS)	1.067282	0.293 (NS)
EF	16.162060	0.000 (HS)	12.848260	0.000 (HS)	6.278787	0.000 (HS)
GH	16.239170	0.000 (HS)	6.959643	0.000 (HS)	7.117816	0.000 (HS)
IJ	12.184530	0.000 (HS)	2.241953	0.031 (S)	1.949525	0.059 (NS)
KL	19.141090	0.000 (HS)	13.213870	0.000 (HS)	9.842433	0.000 (NS)
BC	1.227979	0.227 (NS)	1.358451	0.183 (NS)	0.4835170	0.632 (NS)
DE	10.339620	0.000 (HS)	11.867650	0.000 (HS)	3.0560460	0.004 (S)

	Group II vs. Group III		Group II vs. Group IV		Group III vs. Group IV	
	t Value	*p* Value	*t* Value	*p* Value	*t* Value	*p* Value
AB	1.412403	0.175 (NS)	3.238501	0.005 (HS)	1.826098	0.084 (NS)
CD	1.635849	0.119 (NS)	12.326415	3.272 (NS)	13.962264	4.251 (NS)
EF	3.333333	0.004 (S)	9.942105	9.764 (NS)	6.608772	3.319 (NS)
GH	9.311111	2.648 (NS)	9.152381	3.428 (NS)	0.158730	0.876 (NS)
IJ	9.902912	1.038 (NS)	10.194174	6.638 (NS)	0.291262	0.774 (NS)
KL	5.955737	1.234 (NS)	9.344262	2.510 (NS)	3.388525	0.003 (S)
BC	0.129032	0.899 (NS)	1.714286	0.104 (NS)	1.843318	0.082 (NS)
DE	1.538461	0.141 (NS)	7.338462	8.191 (NS)	8.876923	5.404 (NS)

The Bonferroni's test for comparison of the mean distances between any two groups revealed: significant difference in distances (except inter-abutment distance BC) between group I and group II stone models. Significant difference in distances (except mesiodistal distances AB and inter-abutment distance BC) between group I and group III stone models. Significant difference in mesiodistal distance EF, faciolingual distance GH and inter-abutment distance DE between group I and group IV stone models

The Bonferroni's test for comparison of the mean distances between any two groups revealed: significant difference in the mesiodistal distance EF between group II and group III stone models. Significant difference in the mesiodistal distance AB between group II and group IV stone models. Significant difference in the faciolingual distance KL between group III and group IV stone models

accordance with the recommendation by Bomberg et al. [28]. who referred to Farah et al.

All the impressions were allowed to set on the master model for twice the recommended setting time in the mouth in order to compensate for the polymerization occurring at room temperature (25 ± 2 °C) rather than mouth temperature (32 ± 2 °C) in accordance with ADA specification No. 19 [13, 17, 19, 29–31]. The impressions were poured after 30 min to simulate approximately the elapsed time before an impression could be poured in a clinical situation [4]. Before pouring, all the impressions were stored at room temperature for 30 min in an air tight container with silica gel to simulate a dry environment because if polyethers are stored in contact with moisture, swelling may occur with an accompanying loss of accuracy [32].

Monophase Impression Technique

For group I casts obtained using the monophase impression technique, the results showed a decrease in dimensions as compared to the master model varying between 53 µm (0.553 %) to 57 µm (0.610 %) for the mesiodistal distance, 95 µm (1.035 %) and 57 µm (0.628 %) for the faciolingual distance, 22 µm (0.208 %) and 3 µm (0.029 %) for the inter-abutment distances between die 1 and die 2 and die 2 and die 3 respectively.

The dies produced were found to be undersized for all the distances measured as compared to the master model. The tendency for smaller diameter dies from monophase impression technique was also noted by Stackhouse [33] and Johnson and Craig [34]. This was attributed to the hydrophilic nature of polyether impression materials with a tendency to absorb water and swell in contact with improved stone resulting in smaller dies [35]. The relative uniformity in die size variation may be attributed to the relatively uniform bulk of the impression material used resulting in uniform polymerization shrinkage throughout the body of the impression material [27].

Clinically, smaller die dimensions would result in castings that are too small or too tight [30]. In this situation, laboratory procedures should not only compensate for the cement thickness (20–40 µm) [36] and casting shrinkage of metal but also for the decreased width of the die by using a suitable die relief method. The thickness of one coat of die spacer has been shown to vary from 8–40 µm [9].

One Step Double Mix/Simultaneous Viscosity Impression Technique

For group II casts obtained using the one step double mix technique, the results showed an increase in the dimensions as compared to the master model varying between 18 µm (0.188 %) to 68 µm (0.712 %) for the mesiodistal distances, varying between 22 µm (0.240 %) and 68 µm (0.749 %) for the faciolingual distances. However the inter-abutment distances between die 1 and die 2 and die 2 and die 3 were found to be significantly less than the master model by 76 µm (0.720 %) and 71 µm (0.677 %) respectively.

The dies produced were larger than the master model for all the distances measured except for the inter-abutment distances which were lesser. An in vitro study by Price et al. [37] on the dimensional accuracy of twelve impression materials and die stone combinations also showed stone dies that were larger than the metal master die for polyether when a one step double mix impression technique was used. A similar result of increased mesiodistal and buccolingual dimensions for polyether impression material with the use of a one step double mix impression technique was also noted by Wadhwani et al. [24]. The increase in the mesiodistal dimension was attributed to the unrestricted polymerization shrinkage of the setting material towards the center of the mass in the interproximal areas. The increase in the buccolingual dimension was attributed to the polymerization shrinkage of the impression material occurring towards the mechanically retentive and adhesive coated tray walls.

From a clinical stand point, larger diameter working dies would facilitate complete seating of a restoration [24, 34]. Compensatory application of die spacer could be limited to a single layer.

Two Step Double Mix/Wash Impression Technique

For group III casts obtained using the two step double mix impression technique the results showed an increase in the mesiodistal distances as compared to the master model varying between 14 µm (0.147 %) to 17 µm (0.182 %). The faciolingual distances were found to be less than the master model varying between 14 µm (0.153 %) and 34 µm (0.374 %). The inter-abutment distances between die 1 and die 2 and die 2 and die 3 were found to be significantly less than the master model by 81 µm (0.768 %) and 81 µm (0.773 %) respectively.

This uneven die size variation can be attributed to the use of the cellophane spacer where the thickness of the wash material cannot be controlled leading to a differential contraction of the impression material [16]. In the interproximal areas especially, the adaptation of the cellophane spacer is restricted. However, even though there was an uneven die size variation, the range of discrepancy from the master model was small, varying from −0.773 % (−81 µm) to 0.482 % (48 µm).

Matrix Impression System

For group IV casts obtained using the matrix impression technique, the results showed a decrease in the dimensions as compared to the master model varying between 20 µm (0.214 %) to 57 µm (0.596 %) for the mesiodistal distances, 32 µm (0.338 %) and 37 µm (0.407) for the faciolingual distances and a statistically nonsignificant difference of 1 µm (0.009 %) for the inter-abutment distance between die 1 and die 2. However, the distance between die 2 and die 3 was found to be significantly less than the master model by 23 µm (0.219 %).

The matrix impression thus produced dies that were undersized for all the distances measured. The dimensional variation may have occurred probably due to the uneven thickness provided for the heavy viscosity material caused by the arbitrary scraping of the matrix.

Tjan et al. [19]. stated that differences from the master model of approximately 50.0 µm were acceptable clinically, because they were unlikely to prevent the complete seating of a casting. Overall, it was seen that the accuracy of group III and group IV casts were within this accepted range of 50 µm for most of the measurements except for inter-abutment distances of group III casts and mesiodistal distance of die 1 and abutment height of die 2 for group IV casts.

From the bar charts (Figs. 4, 5, 6), it is evident that the group III stone casts produced by using the two step double

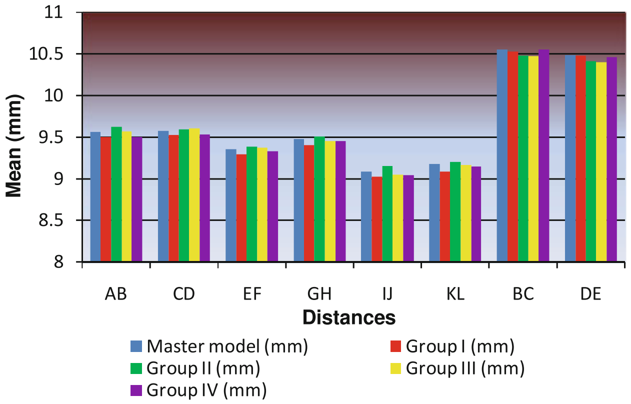

Fig. 4 Multiple *bar diagram* showing a group wise comparison between the master model and the stone models produced by the four impression techniques

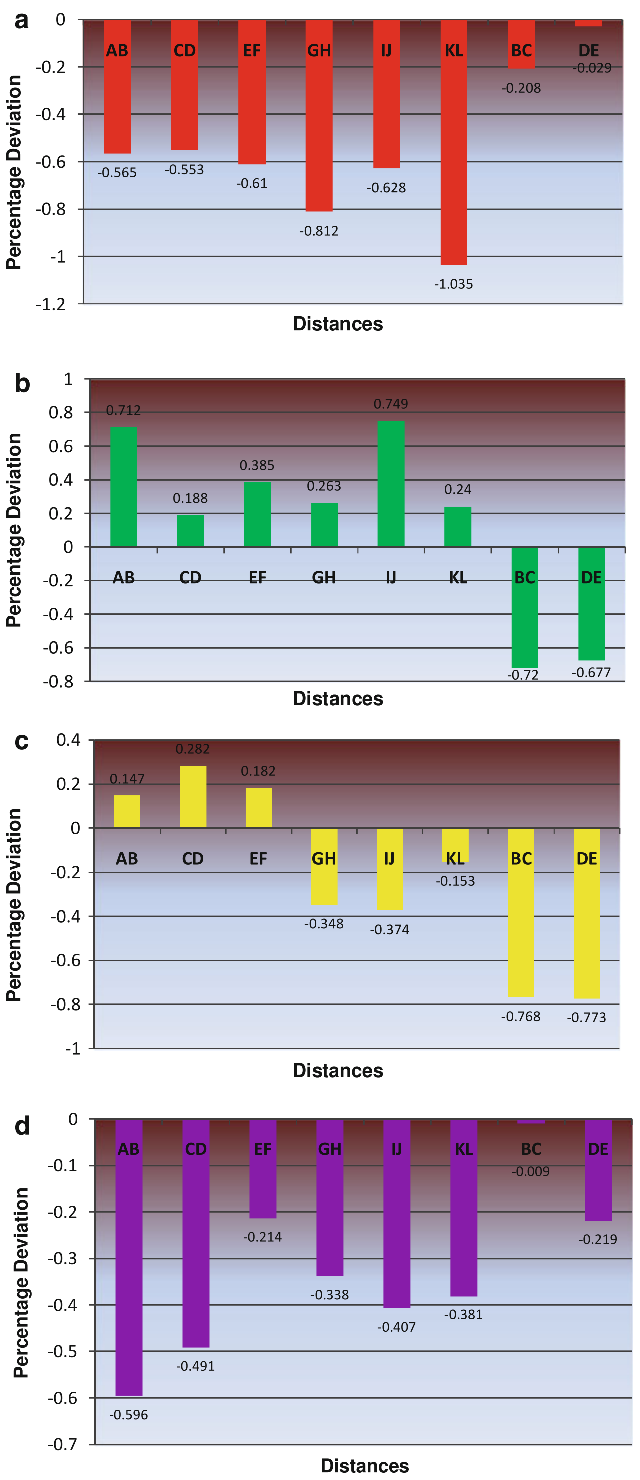

Fig. 5 **a** Simple *bar diagram* showing percentage deviation for the stone models produced by the monophase impression technique. **b** Simple *bar diagram* showing percentage deviation for the stone models produced by the one step double mix impression technique. **c** Simple *bar diagram* showing percentage deviation for the stone models produced by the two step double mix impression technique. **d** Simple *bar diagram* showing percentage deviation for the stone models produced by the matrix impression technique

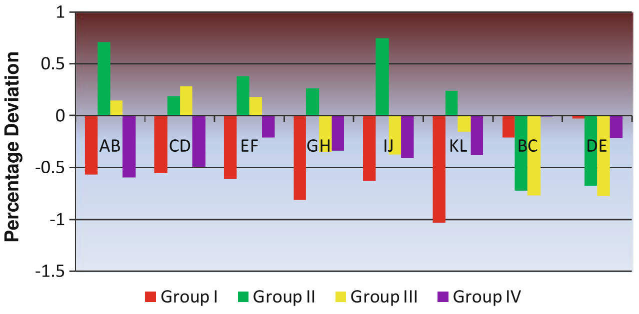

Fig. 6 Multiple *bar diagram* showing a group wise comparison in the percentage deviation between the stone models produced by the four impression techniques

mix impression technique produced casts that consistently showed the least dimensional variations from the master model for most of the distances measured. However, Bonferroni's test for comparison between two groups did not show any statistically significant difference between group III and group IV stone casts for the various distances measured (except for the faciolingual distance KL).

The most accurate results for mesiodistal and faciolingual distances were shown by group III casts. Inter-abutment distances were less than the master model for all the casts (though statistically non significant for group I and distance BC of group IV casts).

The limitation of this study lies with differences in making impressions in vivo compared to in vitro. No moisture equivalent to saliva was used, neither was the biofilm that exists on oral surfaces and comes into contact with the impression material simulated. The effect of seating pressure, impression removal forces and setting expansion of stone was not assessed. The measuring system used was linear, and so did not account for any rotational changes that might have occurred in the shape of the gypsum models.

Conclusion

Within the limitations of this study the following conclusions were drawn:

1. Overall, the two step double mix impression technique yielded casts that showed the least dimensional variation from the master model as compared to the other impression techniques.
2. The matrix impression system also produced casts that were within the clinically accepted range and was not significantly different from the two step double mix impression technique.

3. Monophase impression technique produced casts that showed the greatest dimensional variation for the mesiodistal and faciolingual distances. However, it showed very little dimensional variation for the inter-abutment distances.
4. Casts produced from the one step double mix impression technique and monophase impression technique varied significantly from each other and the other two impression techniques (two step double mix and the matrix impression system) for some of the distances measured. However, the clinical significance of this magnitude of difference between techniques is uncertain.

Acknowledgments Acknowledgements to Sajeesh Daniel Baby, 3D CAD Application specialist on think design software at Think3 design India Pvt Limited and currently working for 3Dconnexion as India Sales manager who helped me with the designing and fabrication of the metal models.

References

1. Wassell RW, Barker D, Walls AWG (2002) Crowns and other extra-coronal restorations: impression materials and techniques. Br Dent J 192:679–690
2. Craig RG, Powers JM (2002) Impression materials in restorative dental materials, 11th edn. Mosby Inc., St. Louis, pp 330–389
3. Keyf Filiz (1994) Some properties of elastomeric impression materials used in fixed prosthodontics. J Islam Acad Sci 7:44–48
4. Eames WB, Wallace SW, Suway NB, Rogers LB (1979) Accuracy and dimensional stability of elastomeric impression materials. J Prosthet Dent 42:159–162
5. Dykema RW, Goodacre CJ, Phillips RW (1986) Impressions and records for indirect procedures in Johnston's modern practice in fixed prosthodontics, 4th edn. W.B. Saunders, Philadelphia, pp 110–129
6. Mondon M, Ziegler C (2003) Changes in water contact angles during the first phase of setting of dental impression materials. Int J Prosthodont 16:49–53
7. Chai JY, Yeung TC (1991) Wettability of non aqueous elastomeric impression materials. Int J Prosthodont 4:555–560
8. Johnson GH, Lepe X (2003) Chee TAw. The effect of surface moisture on detail reproduction of elastomeric impressions. J Prosthet Dent 90:354–364
9. Ceyhan JA, Johnson GH, Lepe X (2003) The effect of tray selection, viscosity of impression material and sequence of pour on the accuracy of dies made from dual arch impressions. J Prosthet Dent 90:143–149
10. Chai J, Takahashi Y, Lautenschlager EP (1998) Chemically relevant mechanical properties of elastomeric impression materials. Int J Prosthodont 11:219–223
11. Lu H, Nguyen B, Powers JM (2004) Mechanical properties of three hydrophilic addition silicone and polyether elastomeric impression materials. J Prosthet Dent 92:151–154
12. Berg JC, Johnson GH, Lepe X, Adán-Plaza S (2003) Temperature effect on the rheological properties of current polyether and polysiloxane impression materials during setting. J Prosthet Dent 90:150–161
13. Craig RG, O'Brien WJ, Powers JM (1996) Dental materials: properties and manipulation, 5th edn. Mosby Inc., St Louis
14. Livaditis GJ (1998) Comparison of the new matrix system with traditional fixed prosthodontic impression procedures. J Prosthet Dent 79:200–207
15. Livaditis GJ (1998) The matrix impression system for fixed prosthodontics. J Prosthet Dent 79:208–216
16. Nissan J, Laufer BZ, Brosh T, Assif D (2000) Accuracy of three polyvinyl siloxane putty-wash impression techniques. J Prosthet Dent 83:161–165
17. Hung SH, Purk JH, Tira DE, Eick JD (1992) Accuracy of one-step versus two-step putty wash addition silicone impression technique. J Prosthet Dent 67:583–589
18. Shekar C, Bhat S, Shetty P (2002) Linear dimensional accuracy of different impression techniques using polyvinylsiloxanes. J Indian Prosthodont Soc l2:12–16
19. Idris B, Houston F, Claffey N (1995) Comparison of the dimensional accuracy of one and two step techniques with the use of putty/wash addition silicone impression materials. J Prosthet Dent 74:535–541
20. Maj Dhiman RK, Agarwal SK, Dhir RC (2001) Dimensional accuracy of putty/wash one step and two step techniques using polyvinyl siloxane impression material: in vitro study. J Indian Prosthodont Soc 1:36–43
21. Gautam N, Sajjan SMC (2003) Matrix impression system (MIS) versus conventional putty reline technique (PRT): a comparative evaluation. The J Indian Prosthodont Soc 3:44–48
22. Jekel JF, Elmore JG, Katz DL (1996) Epidemiology, biostatistics and preventive medicine. W.B. Saunders Company, Philadelphia
23. Chee WWL, Donovan JE (1992) Polyvinyl siloxane impression materials: a review of properties and techniques. J Prosthet Dent 68:728–732
24. Wadhwani CPK, Johnson GH, Lepe X, Raigrodski AJ (2005) Accuracy of newly formulated fast-setting elastomeric impression materials. J Prosthet Dent 93:530–539
25. Bomberg TJ, Goldfogel MH, Hoffman W (1988) Considerations for adhesion of impression materials to impression trays. J Prosthet Dent 60:681–684
26. Petersen GF, Asmussen E (1991) Distortion of impression materials used in the double mix technique. Scand J Dent Res 99:343–348
27. Donovan TE, Chee WWL (2004) A review of contemporary impression materials and techniques. DCNA 48:445–470
28. Bomberg TJ, Hatch RA, Hoffman W (1885) Impression material thickness in stock and custom trays. J Prosthet Dent 54:170–172
29. Johnson GH, Chellis KD, Gordon GE, Lepe X (1998) Dimensional stability and detail reproduction of irreversible hydrocolloid and elastomeric impressions disinfected by immersion. J Prosthet Dent 79:446–453
30. Lepe X, Johnson GH (1997) Accuracy of polyether and addition silicone after long term immersion disinfections. J Prosthet Dent 78:245–249
31. Gordon GE, Johnson GH, Drennon DG (1990) The effect of tray selection on the accuracy of elastomeric impression materials. J Prosthet Dent 63:12–15
32. Williams PT, Jackson GD, Bergman W (1984) An evaluation of the time-dependent dimensional stability of eleven elastomeric impression materials. J Prosthet Dent 52:120–125
33. Stackhouse JA (1975) A comparison of elastic impression materials. J Prosthet Dent 34:305–313
34. Johnson GH, Craig RG (1985) Accuracy of four types of rubber impression materials compared with time of pour and a repeat pour of models. J Prosthet Dent 53:484–490
35. Chai J, Pang IC (1994) A study of the thixotropic property of elastomeric impression materials. Int J Prosthodont 7:155–158
36. Rosenstiel SF, Land MF, Fujimoto J (2001) Contemporary fixed prosthodontics, 3rd edn. Mosby Elsevier, New Delhi (Harcourt), pp 273–312
37. Price RB, Gerrow JD, Sutow EJ, Sween MR (1991) The dimension accuracy of 12 impression material and die stone combinations. Int J Prosthodont 4:169–174