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Comparison of Some Mechanical and Physical Properties of three Types of Impression Materials with Different Dental Implant Angulations

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Choosing an appropriate impression material is a challenge for many dentists, yet an essential component to provide an excellent clinical outcome and improve productivity and profit. The purpose of present study was to compare wettability, tear strength and dimensional accuracy of three elastomeric impression materials, with the same consistencies (light-body). Three commercially available light body consistency and regular set 3M ESPE Express polyvinylsiloxane (PVS), 3M ESPE Permadyne polyether (PE), and Identium (ID), impression materials were compared Tear strength test, contact angle test and linear dimensional accuracy were evaluated for three elastic impression material. Among the three experimental groups PE impression material exhibited the higher mean values of tear strength, followed by ID group then PVS which showed the lowest mean value. For wettability test, Polyether group exhibited the lowest mean values of contact angle, followed by mean values of contact angle of ID group, while the PVS group showed the highest contact angle. There was a significant difference in the linear distance measurements between the two parallel impression coping/analogue assembly of the working models obtained by using (Identium, 3M ESPE Express PVS , 3M ESPE Permadyne polyether). The polyether impression materials provide higher tear strengths and lower wettability than elastomer impression materials and Identium material have acceptable tear strengths and wettability. All three experimental impression materials were distorted in both conditions (angled and parallel implant situations)

Keyword: Polyvinylsiloxane, Tear strength, Polyether, Linear dimensional accuracy.

Choosing an appropriate impression material is a challenge for many dentists, yet an essential component to providing an excellent clinical outcome and improving productivity and profit. However, with the wide array of impression materials available, it is often difficult to choose the proper product for each situation. the accuracy of an impression rely on many factors , so choosing appropriate impression technique combine with the proper impression material reduced the requiring adjustment and lead to a well–fitting restoration [1-3].

Moist environment nature of the mouth suggests that it should be dried with air syringes, anti–sialogogues, cotton rolls, and dry pads cause of saliva are often present along with Crevicular fluid and blood even with the best retraction techniques.

When it comes to precision , the most common elastomeric impression materials currently used for making fixed and removable prosthodontic restorations are polyvinylsiloxane (PVS) and polyether (PE)[2,4].

On one hand, in many situations, polyether provide consistent results. It also can provide good accuracy and surface detail as well as low shrinkage upon setting. Dimensional stability superior to their counterparts PVS[5,6].

Thus even though these decent properties ,it characterized by difficulty of removing impressions made of polyether from the mouth, and also an increased risk of die breakage, could be associated with the lower flexibility of these materials and higher stiffness when compared to other elastomeric materials[6].

On the other hand, polyvinylsiloxane are accurate impression materials with excellent dimensional stability, good detail reproduction, high tear strength, adequate working time, and high recovery from deformation. Although meeting many of the criteria for an ideal impression material, polyvinylsiloxanes intrinsically are hydrophobic in nature, which can result in voids at the margin of the tooth preparation in the impression and bubbles in gypsum casts. However, VPS materials are recently being labeled as hydrophilic due to the addition of extrinsic surfactants[7-9].

The latest class of impression material is the vinyl-polyether hybrids that include identium. .Furthermore, in 2009 presented a newly impression material called vinylsiloxanether (PVSE) (Identium, Kettenbach Company, Eschenburg, Germany). It combined chemically a polyether material and a polyvinylsiloxane, this commercially produced impression material are theoretically claimed to purchase elements, properties, and benefits of both impression materials VPS and PE

PVES is supplied as a 2-paste auto mixing system and contains a polymer with polyether and siloxane (e.g., addition silicone) groups that are promoted as hydrophilic materials that presumably maintain the stability and characteristics of the parent products[10, 11].

The purpose of this study was to compare tear strength, wettability and dimensional accuracy of three elastomeric impression materials, with the same consistencies (light-body).

The null hypothesis stated that there would be no significant difference in tear strength, wettability and dimensional accuracy among polyether vinylsiloxanether and polyvinysiloxane impression.

MATERIAL AND METHODS

Three commercially available light body consistency and regular set 3M ESPE Express polyvinylsiloxane (PVS), 3M ESPE Permadyne polyether (PE), and Identium (PVSE), impression materials were compared. They were supplied by dispensing from auto-mixing cartridges and were used according to manufacturers' instructions. Tear strength test and dimensional changes test and contact angle test were evaluated for three elastic impression material.

Wettability test

Wettability assessed by measuring the advancing contacting of liquid on the surface of the set impression material. Controlled (0.1 ml) volume droplet of distilled water was placed onto specimen surface by means of a micropipette and after one minute measure the angle between the surface of the drop and the surface of specimen by dino-lite microscope was used for imaging the shape of a water drop on the impression material sample surface. The captured image was analyzed by using ImageJ software (ImageJ; USA) to determine the contact angle[12].

Tear strength test

Specimens were divided into three groups (n=5). Groups were immediately removed from the mold and loaded in tension until failure using an Instron testing device (Mensanto, England, Model, WDW-IOOE, No. TC914).

V-notched standard tear strength plastic mold and its riser with the following dimensions was used in this study (101.6mm, 19.5mm,2 mm, length, width and thickness respectively) with v-notched region, this was done according to ISO 34-1:2010, The tear strength was calculated using the following formula:

$Ts = F/d$

Where

Ts: the tear strength (N/mm),

F: the maximum force, in Newton, applied to cause rupture of the specimen,

d : the specimen thickness (mm).

Dimensional accuracy test

Model fabrication

Two block shaped stone models (30mm*20mm*20mm) length, width, height respectively were fabricated. Two holes with a depth of 9 mm were made at 10 mm intervals in each model. These holes will be used to embed the implant analogs. In respect to the first model, the implant holes were prepared with 0–degree angulation, while for the second model the first implant hole was prepared at 0- degree angulation and the second implant hole was prepared at 15-degree angulation.

Implant analogues (Dentium, Seoul, Korea) were inserted in the first hole of each block. Implant analog at 0-degree is used to serve as the reference point angulation, and another implant analogs was inserted in the second hole at an angulation of 15° degrees. The top of the analog was positioned 1 mm above the model.

Fabrication of the special tray

Impression copings were attached to the analogues. Two sheets of modelling wax (Cavex, Holand) were placed to provide space for the impression material.

A cold cured acrylic material was adapted closely to the wax spacer (Super acrylp®P Plus, Czech Republic).

The marked outline of the tray was trimmed. The access was used to construct the handle following the manufacturer's instructions. The tray from the master cast was then removed.

The periphery of the tray was trimmed using an acrylic trimming bur to provide mechanical retention for the impression material, hole of 2mm in diameter were drilled at 10 mm intervals. Stops have been provided in the special tray to ensure the uniform thickness of impressions material. Furthermore, the trays were placed in ivomet to minimize the porosities and to obtain better adaptation.

Impression Making

Three impression material were tested, the impression was taken using a closed-tray indirect technique. All impressions for both the parallel assemblies and the divergent assemblies were performed by the same examiner.

In each master model, impression procedure will be repeated for four times according to the type of impression materials used. A total of 12 impressions procedure will be conducted for each individual master model, giving a total of 24 impressions. Material was injected around the impression coping followed by loading the impression tray with material to seat it on the reference model with gentle finger pressure. Immediately after placing the special tray over the master cast, any excess material was wiped off to verify the complete setting of each tray. The regular set light body impression material were allowed to set as recommended by the manufacturer's instructions for each one of them. Any remaining access impression material was trimmed .Furthermore, the tray was removed after the material was set completely.

Closed-tray impression copings remaining on the master casts upon removal of the tray after the impression material polymerized. These copings were removed one at a time from the master casts and attached to an implant analog. The impression analogue assembly was inserted into the impression by firmly pushing it into place to full depth. Care was taken to ensure the proper seating of the implant replicas in the impression holes. After 15 minutes impressions were poured with high-strength low-expansion die-hard stone (Zhermack technical, Italy), 100g mixed with 20ml of water. The stone was mixed and poured on a vibrator. After one hour and when the stone has set, casts were separated from the impressions and then trimmed and labeled to prepare for the measurements procedure.

Measurement Protocol

All forty experimental casts were measured and examined for linear dimensional accuracy. The distance between the impression coping / analogue assembly on the master model and on the study model was measured and compared using a measuring dino-lite microscope (Dino-lite, Taiwan). It consists of a screen with horizontal and vertical reference lines and was equipped with a light source to project a magnified image of the object onto the screen in the form of a shadow (original magnification ×10), three measurements were made per specimen, and the mean values were computed. Measurements were performed by the same operator to minimize the source of error.

Statistic analysis

One-way ANOVA and Bonferoni test was conducted to analyze study data using IBM SPSs software (Version.23). A P value of > 0.05 was considered statically non-significant (N.S.), d™ 0.05 was considered significant (S.) and < 0.01 was considered as highly significant (H.S.).

RESULTS

Tear strength test

The mean and standard deviation values for tear strength of the three elastic impression material assessed in this study are displayed in (Table 1)

Among the three experimental groups PE impression material exhibited the higher mean values of tear strength (4.261 N/mm), followed by ID group (4.232 N/mm) then PVS (2.420 N/mm) which showed the lowest mean value.

According to ANOVA means of all experimental groups. There were highly significant differences between groups ($p < 0.01$) (Table 2)

Bonferoni post hoc test was conducted to compare mean values of all groups .There was a statistically significant difference from each other ($p<.05$), except between PE and ID groups which was non-significant difference ($p=0.960$) (Table 3).

Wettability test

As for the wettability test, the mean descriptive values of the three impression materials were illustrated in (Table 4). Poly ether group exhibited the lowest mean values of contact angle (39.71000), followed by mean values of contact angle of ID group (46.8) ,while the PVS group showed the highest contact angle (50.02). However ANOVA displayed a statistically significant difference was observed between the groups ($p<0.05$) (Table 5), Bonferoni post hoc test was conducted for all the results, the ID ,PVS and PE showed a statistically significant from each other, except for ID and PVS groups which was no significant difference between them ($p=0.008$) (Table 6).

Dimensional accuracy

Descriptive statistical analysis for parallel implant model after linear measurements of the distance between the heads of the two coping/ analogs assembly of the reference model which was equal to (2.004mm). Mean values of the distance between the two parallel assemblies which were

Table 1. Descriptive statistical analysis for tear strength test

	N	Mean	Std. Deviation	Std. Error	5% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
PE	7	4.261	1.147	0.433	3.199	5.322	2.69	5.75
ID	7	4.232	0.764	0.288	3.525	4.939	3.47	5.32
PVS	7	2.420	1.208	0.456	1.303	3.537	1.15	4.18

Table 2. ANOVA Table for all models included in tear strength test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.571	2	7.786	6.948	0.006 (HS)
Within Groups	20.172	18	1.121		
Total	35.743	20			

Table 3. Multiple comparison Bonferoni test for models included in tear strength test

		Mean Difference (I-J)	Sig.
PE	ID	0.028	1.000
	PVS	1.840	0.013
ID	PE	-0.028	1.000
	PVS	1.812	0.015
PVS	PE	-1.840	0.013
	ID	-1.812	0.015

The mean difference is significant when P values< 0.05

Table 4. Descriptive statistical analysis for wettability test

	N	Mean	Std. Deviation	Std. Error	5% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
ID	10	46.80	3.661	44.180	49.419	41.700	50.100	
PVS	10	50.02	0.567	49.614	50.425	49.400	50.900	
PE	10	39.71	0.593	39.285	40.134	38.900	40.300	

Table 5. ANOVA Table for all models included in wettability test

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	556.442	2	278.221	59.268	0.000
Within Groups	126.745	27	4.694		
Total	683.187	29			

Table 6. Multiple comparison Bonferoni test for models included in wettability test

		Mean Difference (I-J)	Sig.
ID	PVS	-3.22	0.008
	PE	7.09	0.000
PVS	PE	10.31	0.000

The mean difference is significant when P values< 0.05

obtained after setting of stone of the working models was (1.902mm, 1.180mm, 1.163mm) for (ID,VPS ,PE) respectively (Table 7).

Regarding the 15^{0} angulation between the heads of the two coping/analogs assembly the of the second reference model the distance between the two heads was equal to (2.356mm). Mean values of the distance between the heads of 15^{0} angled assemblies which were obtained after setting of stone of the working models was (2.246mm, 1.945mm, 1.163mm) for (ID,VPS ,PE) respectively . Overall results are provided in (Table 7).

Analysis of the data by ANOVA Table demonstrated significant differences in linear distance measurements among groups for both the parallel and angled assemblies of the implant models ($p < 0.01$) (Table 8).

Bonferroni post hoc test revealed significant differences in linear distance measurements between the two reference models the parallel one and the angulated (group R1, R2) and their belonged experimental groups (ID, PVS, PE). However, there was a significant difference among the three groups for both conditions, on the other hand there was no significant difference when readings were observed between (PE and PVS) (Table 9).

DISCUSSION

The null hypothesis was rejected because there were significant difference between the three materials regarding the results of tear strength, wettability and accuracy. From the standpoint of clinical application, the ideal impression material should exhibit high tear strength with maximum energy absorption and minimal distortion[13]. The result revealed that the tear strength of PE and IDENTIUM were significantly higher than PVS, and show no significant difference between each other, this came in contrary with Hondrum *et al.* in 1994[14] who concluded that there were no significantly different between PVS and PE. Also, the results were in disagreement with Lawson *et al.* in 2008[15] who found that PVS showed higher tear strength than PE and PVSE. The reason for this difference may be due to different test method, condition, setting time.

According to the analysis of the mean values of the contact angle obtained from the wettability test, the PE showed the highest degree

Table 7. Descriptive statistical analysis for dimensional stability test

		N	Mean	Percentage changes from the control	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Straight	Control	10	2.004	0%	0.0106	1.996	2.011	1.980	2.023
	ID	10	1.902	5%	0.0811	1.844	1.960	1.705	1.994
	VPS	10	1.180	41%	0.0052	1.176	1.183	1.175	1.185
	PE	10	1.163	42%	0.0151	1.152	1.174	1.132	1.175
Angled	Control	10	2.356	0%	0.0497	2.321	2.392	2.272	2.424
	ID	10	2.246	4.6%	0.0714	2.195	2.297	2.093	2.303
	VPS	10	1.945	17%	0.0370	1.918	1.971	1.900	2.009
	PE	10	1.918	18%	0.0044	1.914	1.921	1.910	1.923

Table 8. ANOVA Table for all models included in dimensional stability test

		Sum of Squares	Df	Mean Square	F	Sig.
Straight	Between Groups	6.159	3	2.053	1181.886	0.000
	Within Groups	.063	36	.002		
	Total	6.222	39			
Angled	Between Groups	1.432	3	.477	212.598	0.000
	Within Groups	.081	36	.002		
	Total	1.513	39			

Table 9. Multiple comparison deferential statistical analysis for dimensional stability test

Dependent Variable			Mean Difference (I-J)	Sig.
Straight	R1	ID	0.101	0.000
		PVS	0.824	0.000
		PE	0.840	0.000
	ID	PVS	0.722	0.000
		PE	0.738	0.000
	PVS	PE	0.016	1.000
Angled	R2	ID	0.110	0.000
		PVS	0.411	0.000
		PE	0.438	0.000
	ID	PVS	0.301	0.000
		PE	0.328	0.000
	PVS	PE	0.027	1.000

The mean difference is significant when P values< 0.05

of wettability followed by ID and PVS impression material. Bonferoni test demonstrated that there was a significant difference between PE and ID group, and also PE and PVS impression materials, however there was no significant difference between ID and PVS.

Higher values of contact angles results in more hydrophobicity, and low values of contact angles results in more hydrophilisity[9]. The results of this study was comparable to the study of Michalakis *et al* ,2007[16], who examined and compared the hydrophilicity of six elastomeric impression materials before and after setting and concluded that PE exhibited the most hydrophilic among all evaluated material.

The recently produced hybrid structure PVES was a composite of two material polyether and polyvinylesiloxane which get benefit from the properties of both material, it's a chemical structure contains polyether which reputed for it hydrophilisity, wettability and precise castability. It is suggested that the addition of polyether to PVS can increase the hydrophilisity of PVS and castability without the need for adding surfactants before impression pouring. This phenomenon can be explained as the following: the mixture of high molecular weight of polyether chains form the backbone frames, and that the smaller PVS molecules attach to the PE backbone. The existence of functional groups of VSE can provide similar hydrophilic characteristics to PE[17].

PE impression material is claimed by its manufacturer as more hydrophilic because of its functional groups [carbonyl (C = O) and ether (C-O-C)]. These oxygen group has more affinity to water[18, 19]. These polarized groups can be attracted and interact with water molecules; this interaction facilitates the contact between impression materials and moist oral tissues [Van Krevelen, 1997][20]. Conventional PVS behaves hydrophobically because it does not contains any polarized groups. A material exhibiting contact angle of greater than 90° is an indication of poor wetting, which means that the material exhibits hydrophobicity, while a material exhibiting contact angle of less than 90° are an indication of better wetting, which means that it exhibits hydrophilicity[21].

Additionally, our results was comparable to the finding of Sheta *et al,* in 2017[20] who concluded that PE and VPES exhibited the higher wettability when the compared with two other group of PVS.

Obviously from the obtained results about the PE and IDENTIUM hydrophilicity, it is inherent in nature for both without the need of adding extrinsic material.

Accuracy of impression is depends on dimensional stability of impression material[22], and influenced by a number of factors such as impression technique, impression tray and properties of the impression materials[23]. An accurate impression is an important step in processing and final fitting of dental prosthesis[24].

Fixture level impression is crucial especially in cases where angulation between abutments and vertical spaces are difficult to be assessed intra-orally [25].

Two impression coping/analogue assembly were placed in each reference model. The first reference model was fabricated with two parallel impression coping/analogue assembly, while the second reference model was fabricated with 15-degree angulations between the fixed assemblies, in order to simulate common clinical situations that may necessitate placement of angulated implants. Furthermore, in contrary of most of previous studies, the implants in this study were tilted to the distal side[26].

With regard to the results compared with the first reference models, measurements (R1), there was a significant difference in the linear distance measurements between the two parallel impression coping/analogue assembly of the working models obtained by using (Identium, 3M ESPE Express PVS , 3M ESPE Permadyne polyether) (2.24644mm , 1.94535mm, 1.16380 mm) respectively as an impression material and measurement of their reference model (2.35670mm). Also the results displayed a significant difference among all the experimental group, with no significant difference observed between polyether and PVS group, this came in agreement with other studies that there was no difference between PVS and PE in multi- implant impression with Vojadni *et al*, 2015[27].

Some studies suggested that PE and PVS perform an accurate results minimum amount of distortion and adequate rigidity[28].

Other study ascertained the superiority of PVS in comparison with PE (29). Some studied indicated the superiority of PE in parallel condition compared to angulate one[30].

In the present study the PE showed some degree of distortion in both parallel and angulated condition. Furthermore, no superiority in comparison between parallel and non-parallel conditions also when it was compared with ID and PVS impression materials.

Attributed lower rigidity of PVS, is considered as alternative. It can be used more safely in partially edentulous particularly in nonparallel situations or in cases with sever undercuts area or multiunit implants and in cases with subgingival implant placement[31]. According to Del'acqua *et al*. in 2008[32] ether should be the material of choice to achieve a more accurate orientation of implant analogues in laboratory master casts. The author also stated that the material rigidity prevents displacement of impression copings within the impression material.

However, Enkling *et al,* in 2012 concluded that there was no significant difference between polyether and PVS. Identium indicated superiority about subjective assessment of the dentist (handling, taste, precision detail of impression) and the dental technician (the ease of removing plaster model from the mold[33].

The results of dimensional measurements in non-parallel conditions show that the polyvinyl siloxane is the best choice, followed by vinyl siloxanether and polyether.

The results of this study were contradictory with Vojdani in 2015, the ID showed a significant difference with PSV and PE. Though, the study detected a significant degree of distortion of ID impression material compared with measurement of R1 and R2, mean values of the working models' measurements were more accurate than PE and PVS mean values[34].

However it is noteworthy that statistical analysis of the measurements' indicated that distortion in all of the impression materials in both parallel and angled condition but consistently.

Some studies claimed that the use of two or three angled implants found to express no signiûcant differences between the angled and parallel implants in terms of misût[35]. Other studies concluded that degree of error is inevitable in all the impression transfer protocols studied[36].

The working models produced by all 3 experimental impression materials were distorted in both conditions (angled and parallel implant) . The measurements detected a reduction in mean values between the reference model and the working cast, the distance between the impression and coping assemblies which is extrapolated to mesio-distal direction in clinical situation. The reduction may be attributed to the shrinkage of impression material toward the center of the mass. This finding was in coordinate with Ceyhan *et al*, in 2003 who found that the distortion of the impression is a concern inherent, in a three-dimensional way, in all of the procedures involved in the indirect dental restorations[37].

Other studies attributed the distortion to the possible inaccuracy of ûxture-level impressions due to difûculties in repositioning the impression coping correctly in elastic material[38, 39].

ADA specification No. 19 described the criteria that elastomeric impression materials should not display more than 0.5% dimensional change after 24 h of polymerization of the material[40], all materials used in this study were within the accepted stander .

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