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Research Article

Wettability and Tear Strength of Two Novel Materials for Recording Impressions of Post Hole Spaces

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Abstract

Newer elastomeric impression materials have been introduced into the market and clinical used but there are still insufficient data about their tear strength or their wettability. The purpose of this study was to compare the wettability and tear strength of two impression materials for post hole space. Thermoplastic resin and vinylsiloxanether impression material were used. For wettability test, 10 disc shaped specimens (32 mm diameter and 3 mm thickness) from each material used were prepared using a custom made brass mold. Wettability was measured by measuring the contact angles (θ) that is made by a drop of gypsum slurry with the specimens using sessile drop technique. For tear strength testing, 10 specimens of each impression material were fabricated from a gypsum mold with dimensions identical to that specified in ASTM D624-911 for trouser tear (150 X 15 X 2 mm). Each specimen was subjected to tension until failure using an Instron testing device at a constant head speed of 50 mm/min. Tear strength and contact angle data were summarized using means and standard deviations. Comparisons between results of the two materials were done using the independent t-test.

Results of the current work revealed that the contact angle was significantly higher for vinylsiloxanether 30.7º than that of thermoplastic resin 50.6º ($p < 0.001$) and the tear strength was significantly higher for thermoplastic resin 20.5N/mm than that of vinylsiloxanether 10.3 N/mm ($p < 0.001$). Considering the limitations of this *in vitro* study, it was shown that:

- Thermoplastic resin can be used to register post space wherever tear resistance is of prime concern.
- We should use VSE is a preferred choice if moisture control cannot be guaranteed during impression taking.

Keywords: *Vinylsiloxanether Impression Material; Thermoplastic Resin; Wettability; Contact Angle; Tear Strength*

Introduction

Vinylsiloxanether Impression Material

Impression materials are used to obtain an accurate replica of hard and soft oral tissues. Recently, vinylsiloxanether (VSE) products were commercially introduced. These elastomeric impression materials are combinations of vinyl polysiloxane (VPS) and polyether (PE) and are promoted as hydrophilic materials that presumably maintain the stability and characteristics of the parent products [1,2].

VSE combines the most desired properties from addition silicone and polyether impression materials into one material. This has been claimed by the manufacturer to possess acceptable mechanical and flow properties, besides its unique wetting characteristics. Moreover, the accuracy of impressions is improved by its enhanced hydrophilicity resulting in improved flow with recording of finer details of impression and during pouring this impression for model fabrication. They are supplied as a 2-paste automixing system. Little independent evaluation is available on this material, but manufacturers' data suggests that these products are hydrophilic during setting and after polymerization [1,2].

Thermoplastic Resin Impression Material

Patterns for post core can be constructed directly by heating the thermoplastic resin over a flame until the material, or heat the resin in a low-temperature glue gun. Apply a small amount of the heated resin to the apical end of the plastic rod to cover two thirds of the anticipated length of the post pattern. Insert the rod into the prepared post space and lift it after 5 to 10 seconds and reseat. Inspect the post pattern for completeness. Fabricate the core with conventional autopolymerizing resin. If the indirect technique is preferred, pick up the thermoplastic resin pattern with an elastomeric impression material, which can be poured in the conventional manner. Soak the cast in warm water to help release the pattern. Reseat the post pattern, and wax the core. Invest and cast the post and core restoration [3].

The resin flows well and thereby reduces voids. The resin is elastic enough to be removed from small undercuts without locking into the canal or fracturing [4].

Thermoplastic polymer- Macromolecule material made of linear and/or branched chains that softens when heated above the Tg, molded to a new shape, and then cooled below the Tg to retain the new configuration. The setting reaction is reversible because of the relatively weak bonds among the molecular chains [5].

In a previous work the dimensional accuracy and detail reproduction of this thermoplastic resin were evaluated when used as pattern or impression material for posts. Results of this study showed that there was no statistically significant difference in surface detail reproduction as well as dimensional stability during hardening between thermoplastic resin, cold-cure resin pattern material or polyether elastomeric impression material [6].

Wettability and Contact Angle

Impression materials hydrophilicity is critically important to wet the hard and soft-tissues in the mouth and to create accurate impressions and casts [7]. Only when the impression material is hydrophilic, can water be displaced and can the material ideally adhere on these surfaces [8]. Considering the impact of hydrophilicity on accurate die casting [9], inadequate wetting results in gypsum casts and dies producing pits and voids [10] located in critical areas such as margins, pin holes, and retentive grooves [11].

Wettability is determined by measuring the magnitude of the contact angle that is formed between the drop of liquid and the surface in question [11]. The contact angle is usually calculated using the Young-Dupré equation [12].

Complete wetting occurs at a contact angle of 0°, and no wetting occurs at an angle of 180° (Figure 1).

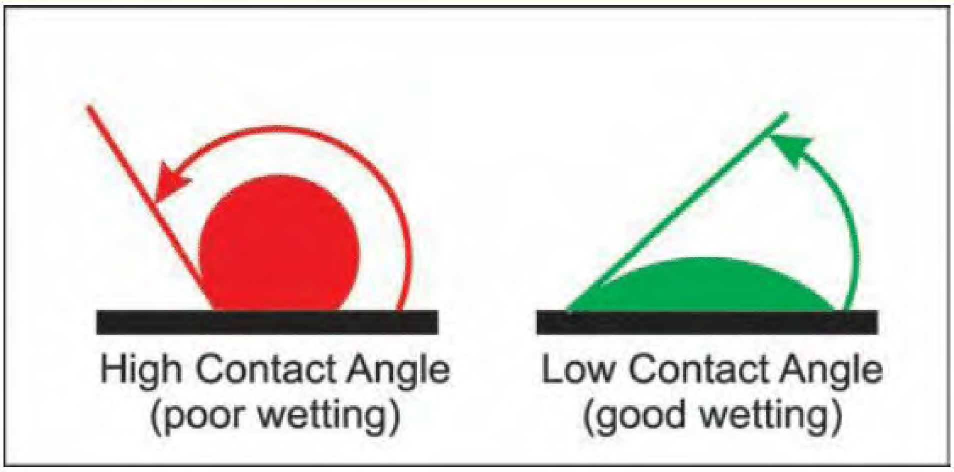

Figure 1: *Contact angle measurements demonstrate a liquid's ability to wet a surface.*

Example of wetting in dentistry occurs when a gypsum product (plaster) is poured into an impression. The mixed material wets the surface of the impression material, the fine details of the impression will be reproduced in the cast. If poor wetting occurs, bubbles will likely result in insufficient detail and an unusable cast [13].

Contact Angle Measurement

The most commonly used method is the drop shape analysis (DSA) [14] of the image of a sessile drop deposited on a solid (Figure 2). It is an image analysis method for determining the contact angle from the shadow image of a sessile drop and the surface tension or interfacial tension from the shadow image of a pendant drop. An image of the drop is recorded with the help of a camera and transferred to the drop shape analysis software. A contour recognition is initially carried out based on a grey-scale analysis of the image. In the second step, a geometrical model describing the drop shape is fitted to the contour. The contact angle is given by the angle between the calculated drop shape function and the sample surface, the projection of which in the drop image is referred to as the baseline. The surface tension is always calculated with the help of a Young-Laplace fit to the contour of a pendant drop determined by image analysis.

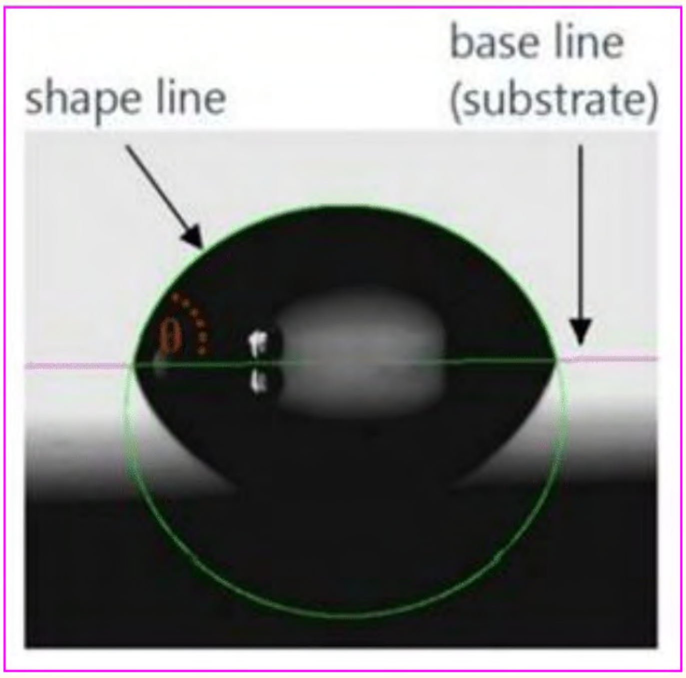

Figure 2: *Sessile drop with fitted contour (shown in green).*

The contact angle θ results from the equilibrium between the interfacial tensions (γ) of the solid, the liquid and the gas phases involved (Figure 3) namely: γSV, γSL, γLV with "S", "V," and "L" referring to the solid, liquid and vapour phases, respectively. The equation governing the force balance at an interface is Young's equation (1):

$$\gamma SV - \gamma SL = \gamma LV \cos\theta \quad (1)$$

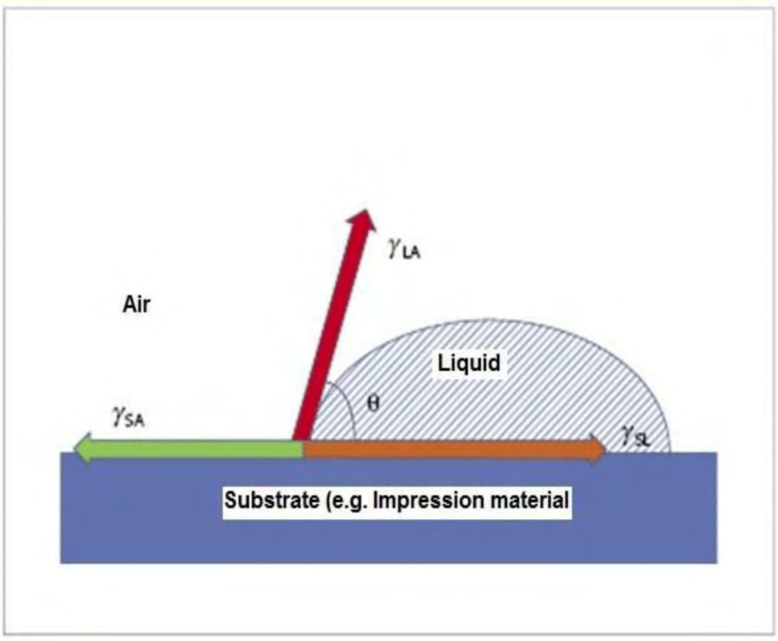

Figure 3: *Balance of forces.*

Tear Strength

Impressions should resist tearing when tensile stresses are applied during impression removal and cast separation from the set impression. Impression materials are most susceptible to tearing in gingival crevices and interproximal areas. Tearing in the impression causes defects, which affect the accuracy of the final restoration [15]. Additionally, some impression material remnants remaining in the sulcus may produce inflammation reactions [16,17]. Therefore, it is necessary for impression materials to have maximum tear strength at the time of removal [18].

The tear strength of impression materials has been measured using several different tests, including the Trouser tear test [19-21]. It is a measure of the resistance of a material to tearing forces. The tear strength of the notched specimen is calculated by dividing the maximum load by the thickness of the specimen. The unit of tear strength is N/mm [22].

A thin section of impression material, such as that found in the depth of the gingival sulcus, at the end of post hole space, and at the depth of the anti-rotational groove is prone to tear. The destruction of an essential portion of an impression renders it useless. In this regard, adequate tear energy of the impression material is crucial to minimize tear. The tear energy of elastomeric as impression materials has been well documented in the literature [23].

Although new elastomeric impression materials have been introduced into the market, there are still insufficient data about their mechanical features. One study investigated the tensile properties of 3 hybrid vinyl polyether silicone-based impression materials (from the same family of vinylsiloxanether) were tested. In this study, it was concluded that the light-body vinyl polyether silicone showed high tensile strength, yield strength, and adequate strain at yield/brake; those features might help to reduce tearing phenomena in the thin interproximal and crevicular areas [24].

There is no information about the wettability and tear strength at all for the thermoplastic resin and fewer information about those of vinylsiloxanether elastomeric impression material. The purpose of this investigation was to comprehensively study the tear energy and the wettability of the two materials used in the current work.

Materials and Methods

Materials

Thermoplastic resin (Figure 4) [cast posts and plastic, Merritt EZ Cast Post Inc., Hendersonville, N.C.] and Vinylsiloxaneether impression material (Figure 5) [Identium medium fast, Kettenbach GmbH and Co. KG. Germany] were used.

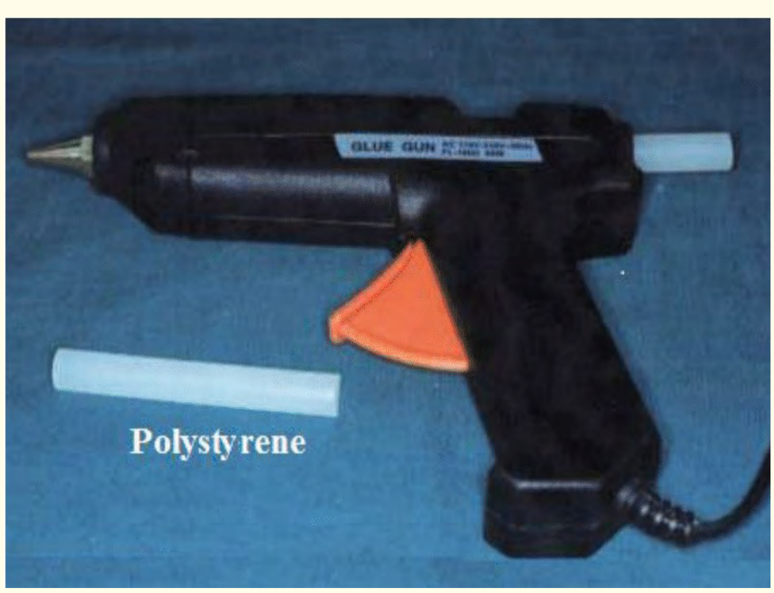

Figure 4: *Polystyrene thermoplastic resin sticks.*

Figure 5: *Vinylsiloxanether impression material.*

Methods

Wettability Testing

Specimens Preparation

VSE impression material was hand mixed as specified by the manufacturer. A disc shaped specimen of 32 mm diameter and 3 mm thickness were prepared using a custom made brass mold. The mold was placed on a clean glass plate and was slightly overfilled with the material. Another glass slab of the same size was placed on top of the mold and hand pressed for 30 s to obtain a flat surface specimen. These were allowed to set for the time suggested by the manufacturer. The resulted sample has a disk shape, with thickness of 3mm and a diameter of about 32 mm. For TR the same sample was prepared with the same dimensions but from the softened thermoplastic resin by its heating.

All specimens were inspected, and those with surface defects were discarded and remade. Impression samples were handled with forceps throughout the experiment and immediately placed in a container, to avoid contamination of the surface of the samples [25].

Contact angles (θ) measurement by sessile drop technique

The surface wettability of these specimens was evaluated by using the Digital Microscope (Scope Capture Digital Microscope, Guangdong, China) to measure the contact angle. Each specimen was mounted on the mechanical stage of the goniometer. The specimens were positioned one by one on a flat surface in the measuring device. A saturated solution of calcium sulfate dihydrate (0.2 g/ml) in distilled water was used as the wetting liquid. This solution simulates the liquid phase of gypsum slurry. A calibrated microburette was used to place a drop (0.05 ml) of the saturated solution of calcium sulfate dehydrate over the surface of each specimen. The volume of each solution was controlled by means of a micro-pipette (Eppendorf Reference, adjustable-volume, Hamburg, Germany). This micro-pipette could be manually maneuvered through a tiny hole on the top of the measuring device. One droplet of solution was deposited on each sample surface. The mechanical stage was adjusted until the definite inverted image of the drop was clearly visible through the eye piece of the Digital Microscope. The view through the eye piece showed a horizontal axis that was adjusted to the surface of the sample and a vertical axis that was adjusted to form a tangent to the curved surface of the drop. The contact angle was visually measured by using the protractor and micrometer scales of the Digital microscope from the flat surface of the impression material to a line that formed a tangent with the drop at the point of the solid-liquid interface [25]. This procedure was repeated by placing a drop of wetting liquid at six different sites over the surface of each sample. The readings were taken within 1 min after the drop was placed. Six readings were taken of each of the 20 specimens, and the mean of the six readings was calculated to obtain the final reading for each specimen. The acquired images were analyzed by Image J software (Image J, Earl F, Glynn II, Over Park, USA), and contact angles were provided. The values were averaged to produce 1 contact angle for each 20 specimen.

Tear Strength Test

Ten specimens of each impression material were fabricated from a mold with dimensions (Figure 6) identical to that specified in ASTM D624-911 for trouser tear (150 X 15 X 2 mm) [26].

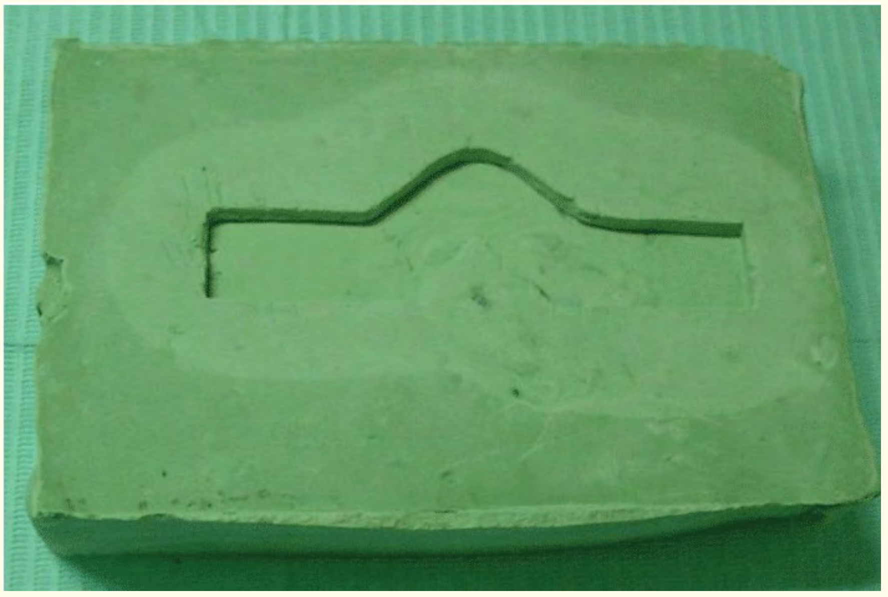

Figure 6: *Un-nicked 90-degree angle shaped specimens according to American Society for Testing and Materials (ASTM) No.D624-911 for tear strength testing.*

Specimens (Figure 7,8) was subjected to tension (Figure 9,10) until failure (Figure 11) using an Instron testing device (Instron Corp., Canton, MA, USA) at a constant head speed of 50 mm/min.

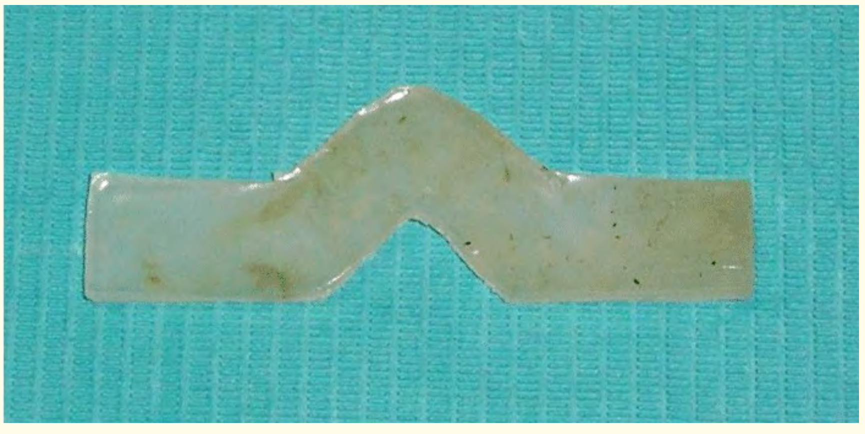

Figure 7: *A specimen of thermoplastic resin.*

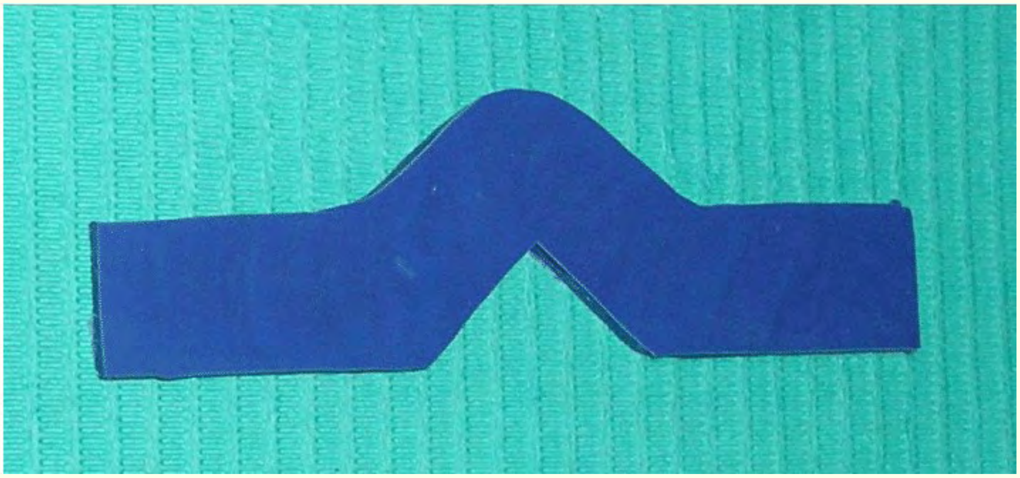

Figure 8: *A specimen of medium viscosity vinylsiloxanether.*

Figure 9: *Tear strength thermoplastic resin specimen in the Instron testing device.*

Figure 10: *Tear strength testing of vinylsiloxanether.*

Figure 11: *Specimen after complete tearing.*

Tear strength was calculated in N/mm according to the following formula:

Js = 2 F/d

where F = the mean force during rupture and d = the thickness of the test pieces in millimeters- All specimens were inspected for any gross defects before and after testing.

Statistical Methods

Data management and statistical analysis were performed using the Statistical Package for Social Sciences (SPSS) vs. 21. Tear strength and contact angle data were summarized using means and standard deviations. Comparisons between the 2 materials were done using the independent t-test. All p-values are two-sided. P-values ≤ 0.05 were considered significant.

Results

Contact Angle

Results of the current work revealed that the contact angle was significantly higher for VSE (30.7º) that of TR (50.6º) p < 0.001 as shown in Table 1 and Figure 12.

***Table 1**: Contact angles of the tested materials (MEAN ± SD).*

	TR		VSE			
	Mean	**SD**	**Mean**	**SD**	**MD ± SE**	**P value**
Contact Angle	50.6º	5.8	30.7º	4.0	19.9 (15.2 - 24.5)	< 0.001

P ≤ 0.05 is considered statistically significant.

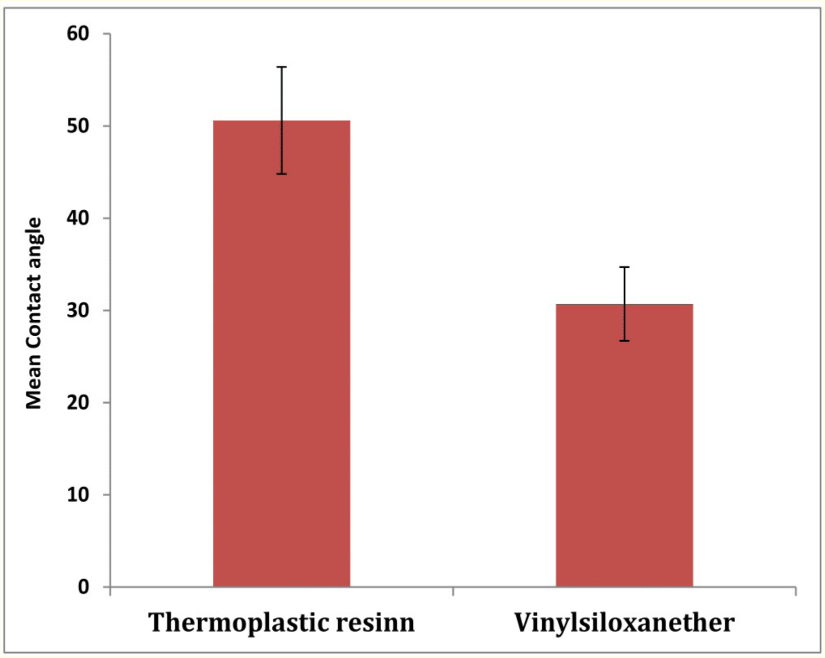

***Figure 12:** Contact angles (mean ± SD) for TR and VSE.*

Representative captured photo for the wetting solution drop on the surface of horizontally-fixed TR sample is shown in (Figure 13) and that for VSE sample is shown in (Figure 14).

Figure 13: *Captured photo for the wetting solution drop on the surface of horizontally fixed TR sample.*

Figure 14: *Captured photo for the wetting solution drop on the surface of horizontally-fixed VSE sample.*

Tear Strength

Results of the current work revealed that the tear strength was significantly higher for TR 20.5 N/mm than VSE 10.3 N/mm $p < 0.001$ (Table 2 and Figure 15).

Table 2: *Tear strength (N/mm) of the tested materials (MEAN ± SD).*

	TR		VSE			
	Mean	**SD**	**Mean**	**SD**	**MD (95% CI)**	**P value**
Tear Strength	20.5	3.8	10.3	1.8	10.2 (7.3 - 12.9)	< 0.001

P ≤ 0.05 is considered statistically significant.

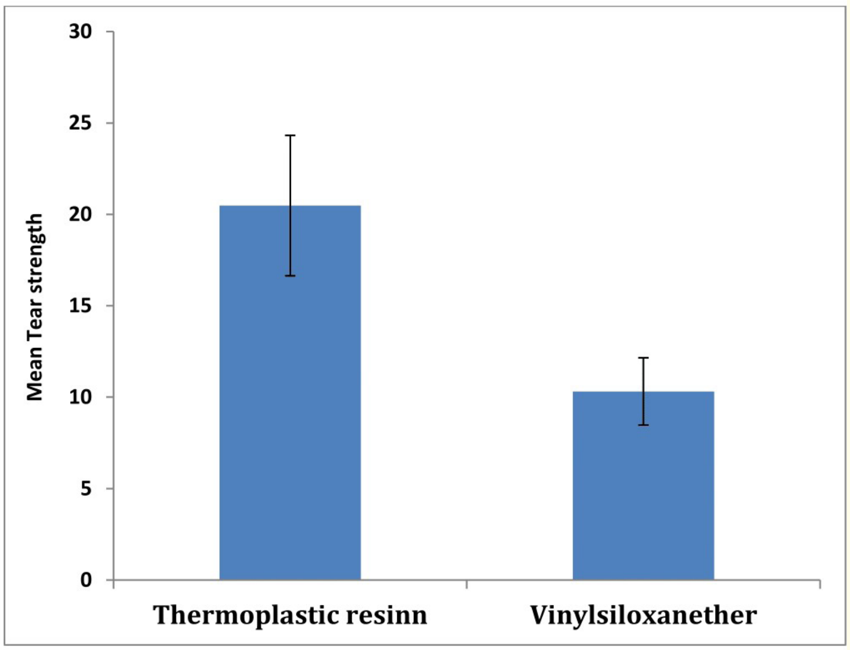

Figure 15: *Tear strength (mean ± SD) for TR and VSE.*

Discussion

Wettability

There is no standard accepted method for contact angle determination [27]. In the current work, the sessile drop method was employed because it is regarded as an appropriate mean of measurement to assess the hydrophilicity of impression materials [28,29].

Contact angle measurement was performed by the use of saturated solution of calcium sulfate dihydrate (0.2 g/ml) in distilled water instead of pure water as the wetting liquid. This solution simulates the liquid phase of gypsum slurry during pouring the impressions. The result of this study showed that VSE showed much lower value of contact angle 30.7 º than TR 50.6 º the wettability VSE, which can be regarded as a mixture of polyether and polyvinyl siloxane, is from its chemical structure as that in PE, which is important both for castability and impressed surfaces. This is in agreement with the little independent evaluation that is available on the VSE where their manufacturers' data suggests that these products are hydrophilic during setting and after polymerization [30].

Some authors explained VSE hydrophilicity because it contains large molecular polyether (PE) chains form the backbone frames, and that the smaller polyvinyl siloxane (PVS) molecules attach onto the PE backbone. The existence of functional groups of VSE can provide similar hydrophilic characteristics to PE [31]. 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 polarized groups can attract and interact with water molecules; this interaction facilitates the contact between impression materials and moist oral tissues [32]. Conventional PVS behaves hydrophobically because it does not contain 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 and a material exhibiting contact angle of less than 90° are an indication of better wetting, which means that it exhibits hydrophilicity [33].

The contact angle of TR recorded in the current work was 50.6º. This contradict the results obtained by the study done by Kumiko., *et al*. (2013) who measured the contact angle of pure water with the surface of untreated TR and found it of around 80º [34]. This could be attributed to the reduction in surface tension of the gypsum slurry when used as the wetting solution in our work instead of pure water used in their research.

Although the results of the current work showed that VPE having higher contact angle than TR but both are less than 90° which indicates better wettability for both.

In conclusion, the wettability of the new generation of impression material VSE is superior to that of TR.

Tear Strength

During impression taking for a tooth having post hole space (s), the impression material must withstand the tearing forces associated with separating it from the tooth. The clinical tear performance of impression material appears of prime importance [35]. Tear strength is the result of complex interactions between material composition, flow to a particular film thickness, release properties from the tooth and the gypsum model, presence of internal and surface defects, and rate of with which the impression is withdrawn. Because of the complexities of integrating and measuring these properties, laboratory tests evaluating the propagation energy of a tear have been employed as common ways to evaluate elastic dental materials [20,36]. Tear, tensile, and yield strengths are important properties for impression materials; they have been investigated by several studies [19,20,23,37].

From the standpoint of clinical application, materials with high tear strength are superior to the materials with low tensile strength. This means that the ideal impression material should exhibit maximum energy absorption without tearing and with minimal distortion. For the aforementioned reasons the tear strength was investigated in the current work. Results of this work revealed that the tear strength was significantly higher for TR 20.5N/mm than VSE10.3 N/mm $p < 0.001$.

Re D., *et al*. (2015) showed that VSE showed higher in vitro results for yield strength and tensile strength at break than polyether [24]. Our results cannot be compared to them because of the different mechanical testing used in our studies where they measured tensile strength but we measured tear strength.

TR showed higher tear strength than VSE this can be attributed to the higher viscosity of the former than that of the later. The VSE used in the current work was of medium viscosity.

Conclusions

Considering the limitations of this in vitro study, it was shown that:

- Thermoplastic resin can be used to register post space wherever tear resistance is of prime concern.
- We should use VSE is a preferred choice if moisture control cannot be guaranteed during impression taking.

Clinical Relevance

TR is a cheap, easily manipulated, elastic material, and as accurate and dimensionally stable as the rigid cold cure resin pattern. Hence, it can replace impression materials for post space registration. Under this condition TR impression material is considered to be of low hydrophilicity and to improve its wetting by an aqueous solution of a gypsum-forming model material we can ask their manufacturer to change the formulation to render the material more hydrophilic.

When using VPSE impressions materials for post hole recording it recommended to remove it with a snap motion during its withdrawal from the tooth or from the cast after its pouring.

Conflict of Interests

The authors of this paper certify that they have no proprietary, financial, or other personal interests of any nature or kind in any product, service, and/or company that is presented in this work.

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