COMPARISON OF THE PENETRATION ABILITY OF DIFFERENT ELASTOMERIC IMPRESSION MATERIALS INTO A THREE-DIMENSIONAL GINGIVAL MODEL

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BY

PHICHAYA SUWANWALAIKORN

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This study aimed to compare the penetrative ability of elastomer impression materials in a three-dimensional gingival sulcus model. Four types of elastomer (polyether, polysulfide, addition curing silicone and vinylpolyethersiloxane) were tested, using models with three sulcular widths (0.2mm, 0.2mm and 0.05 mm). Six impressions were taken for each width with one material type. They were measured by a stereomicroscope (Olympus SZ61) and interpreted by image analysis software (Image-Pro Plus). A two-way ANOVA and Dunnett T3 test were performed, with the level of significance (p-value) set at p£ 0.05. The results of this study showed no statistically significant differences among four elastomers for a 0.2 mm and 0.1 mm gingival sulcus. For a 0.05 mm sulcus width, polysulfide demonstrated the best penetration ability and flowability into the sulcus. This was statistically higher than additional curing silicone and vinylpolyethersiloxane. In conclusion, in a gingival sulcus of more than 0.1 mm width, all four elastomers had similar penetrative ability, but polyether held the highest score for the 3D model.

Keyword : Penetration ability, Elastomeric impression materials, 3D gingival model

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CHAPTER 1
INTRODUCTION

Background

The impression materials plays an important role in the process of restoration fabrication. It transfers the details of tooth structure required for laboratory work. Impression materials is a one of the essential keys for constructing crown or bridge. High quality of dental impression is a essential for successful fixed prosthodontic work. Dental impression should be able to provide accuracy, good dimensional stability, elastic recovery, biocompatibility and non-toxicity to the oral cavity.[1-3] All of these properties are the ideal properties. Other desirable characteristics include flowability and hydrophilicity especially when the margin is subgingival.

There are various kinds of impression materials available in the market. Elastomeric materilas are commonly used for crown fabrication such as polysulfide(PS), additional silicone or polyvinylsiloxane(PVS) and polyether(PE), are commonly used for crown fabrication. Each elastomeric type can be used in several condition, depending on the type of restoration, material properties and patient's condition. Although elastomeric materials are well known for replicating crowns and bridges, one of the major challenges for impression is the subgingival margin of tooth preparations due to factors, such as salivation, bleeding or sulcular fluid. These factors are deemed critical especially in cases where the finishing lines for fixed restorations lays subgingivally. The aforementioned factors could also lead to an inaccurate impression and marginal discrepancy which ultimately increase the risk of secondary caries and affect the periodontal health. To avoid these problems, the key success factors, consisting of a definite finishing line, a suitable sulcus opening and a dry environment, are required. Nevertheless, qualified impression material properties and suitable impression technique are also vital.

Polysulfide is the first ever elastomeric impression materials. It had been used for several decades due to its good detailed reproduction and dimensional stability. But its usage had decreased over time because it can stain clothes, has an unpleasant odor and strong bitter taste. Later, addition curing silicone has emerged into the market. Addition silicone, which is also known as polyvinylsiloxane, has high accuracy, good dimensional stability, good elastic properties, high tear strength and excellent flow. However, it is hydrophobic which makes it difficult to capture the details subgingivally with high moisture. At present, polyether, which is hydrophilic and suitable for capturing the subgingival details, is widely used. This type of material hardens when it is fully set. Therefore, it is difficult to remove the impression at the area of undercuts both intra- and extra-orally. A recently developed material called “vinylsiloxanether" has combined polyether with additional silicone. This new product is hydrophilic, has superior property of great detail reproduction and better elastic property after fully set. Hence, it is easier to remove when the undercut is presented.

To make a proper impression, abutment condition and gingival management are as important as the impression itself. Restoration margin position relative to the gingival margin is a significant factor to control the gingival health.[4] Supraginigval margin is desirable for the gingival health unless supragingival cannot be obtained. Hence, margin need to be subgingivally. Subgingival margin placement is required for several reasons such as to cover old restorations or decay, to increase the length of tooth structure and to increase the esthetic in anterior teeth. When tooth preparation produced a subgingival finishing line, it is rather difficult to take an impression because of its technical sensitivity including difficulty inaccessibility, fluid control of blood or gingival fluid and the width of the ginigval sulcus. Aimjirakul N (2005) studied the prevalence of finishing line location of prepared teeth which showed that 80.0% of the 60 post and core preparations involved equi-gingival or subgingival finishing line[5] Therefore, management of subgingival restorative margins is a crucial factor in achieving an excellent restoration. Consequently, this leads to the purpose of this research which is to compare the penetration ability of different impression materials into the gingival sulcus in order to find the most suitable impression materials for subgingival restorative margin.

Objectives of this study

- To compare the penetration ability of different elastomeric impression materials into the 3-dimensional gingival model
- To use the knowledge acquired for clinical application

Limitations of this study

This study is based on laboratory experimental research.

Conceptual framework

Types of impression material

1. Polyether (Impregum™, 3M ESPE, Germany) 2 viscosities: medium body and light body
2. Addition curing silicone (Provil® novo, Heraeus Kulzer, Germany) 2 viscosities: medium body and light body
3. Polysulfide (Permlastic™, Kerr, Germany) 2 viscosities: regular body and light body
4. Vinylsiloxanether (Identium®, Kettenbach, Germany) 2 viscosity: medium body and light body

⇩

Gingival sulcus width

1. Gingival sulcus width 0.2 mm
2. Gingival sulcus width 0.1 mm
3. Gingival sulcus width 0.05 mm

⇩

The penetration distance into the 3-dimensional gingival model

Figure 1 Conceptual framework

Variables for this study

1. Independent variable

   Elastomeric impression materials

   1.1 Polyether (Impregum™, 3M ESPE, Germany) 2 viscosities: medium body and light body

   1.2 Addition curing silicone (Provil® novo, Heraeus Kulzer, Germany) 2 viscosities: medium body and light body

   1.3 Polysulfide (Permlastic™, Kerr, Germany) 2 viscosities: regular body and light body

   1.4 Vinylsiloxanether (Identium®, Kettenbach, Germany) 2 viscosity: medium body and light body

2. Dependent variable
   - Penetration length into the 3-dimensional gingival model

3. Controlled variable
   - Temperature
   - Environment
   - Humidity

Hypothesis

H_0: There is no significant difference in the penetration ability of different elastomeric impression materials into the 3-dimensional gingival model

H_1: There are significant differences in the penetration ability of different elastomeric impression impression materials into the 3-dimensional gingival model

CHAPTER 2
LITERATURE REVIEW

For the purpose of this study, the review of the literature was presented to address five related topics as follows:

1. Dental impression material
2. Elastomeric impression material
3. Impression technique
4. Sulcus width
5. Penetration test

Dental impression material

Dental impression can be defined as a negative likeness or copy in reverse of the surface of the teeth and adjacent structures for use in dentistry.[2] It is mainly classified into two groups: non-elastic impression material and elastic impression material (Table1).

Table 1 Types of impression material

Non-elastic impression	Elastic impression	
	Hydrocolloid	Elastomer
- Wax - Plaster - Compound	- Reversible hydrocolloid - Irreversible hydrocolloid	- Polysulfide - Silicone - Condensation silicone - Addition silicone - Polyether

In the 1700s, the first impression technique was established by a German surgeon using beeswax. Wax was the only impression material used in dentistry until mid 19th century, then plaster of paris was introduced.

Hydrocolloid was discovered in 1925. It was divided into reversible and irreversible hydrocolloid. Reversible hydrocolloid was also known as agar. The reason it was called reversible was because of its physical property which can be reversed repeatedly between the fluid and solid form through heating and cooling. This resulted in its special feature as it can be reused for multiple times. However, it required the use of controlled water bath and individual tray with expensive materials and equipment. Hence, it was not commonly used up until today.

Alginate was introduced later on as an elastic, irreversible hydrocolloid impression material that was inexpensive, easy to use and did not require a lot of equipment. Due to its various advantages, it was widely used among many dental practices. Nonetheless, it still had its fallbacks being dimension instability and poor detail reproduction which then led to the discovery of other impression materials.

Condensation silicones and Polysulfides were used in fixed prosthodontics in ealy of 1950s. Although the disadvantage of polysulfide was shrinkage over a period of times due to the evaporation of water. Along with unpleasant odor, it can be messy and stain on clothes, leading to less popularity over a period of time. In the late 1960s, polyether was reveal into the market. Its hydrophilic, high mechanical properties and excellent dimensional stability made it superior to hydrocolloids and C-type materials. Addition silicone or polyvinylsiloxane was evolved ten years later. Polyvinylsiloxane was preferred over other materials due to its advantages of excellent accuracy, long-term dimensional stability and elastics recovery. However, polyvinylsiloxane was categorized as hydrophobic and surfactants were added to increase its hydrophilicity which made the impression more precise.

Until recently, a new material has been developed which combined polyether polymer and vinyl group of polyvinylsiloxane together. It was called vinyl polyether siloxane.

Elastomeric impression material

At present, there are four types of elastomeric impression materials in the field of dentistry: polysulfide, addition curing silicone, polyether and vinylpolyethersiloxane.

Polysulfide

Polysulfides, commonly known as rubber base, was introduced in mid-1950s. The base consists of a polysulfide polymer (-SH group), titanium dioxide, or silica and the accelerator is lead dioxide. Polysulfides are available in three viscosities; light, regular and heavy. They have excellent tearing resistance, good detailed reproduction, good flow and moderate hydrophilic which is suitable for capturing a subgingival margin upon impression. Polysulfide is not a rigid material so the impressions are easier to remove when compared with polyether.[6]

Working time and setting time are relatively long, which is an advantage when impressions are being taken for multiple preparations. However, this can become a downside when impressions are being taken for a few teeth. The disadvantages of polysulfide are unpleasant odor, strong bitter taste, staining, handling difficulty and it requires an individual tray when used. All of these factors lead to less popularity among the dental practice. Furthurmore, they must be poured as soon as possible after impression making because delayed pouring can result in a clinically significant dimensional change.[7]

Addition curing silicone

Addition curing silicones or polyvinylsiloxane impression material was introduced in the mid-1970s. It is similar to condensation silicone except that it has much greater dimensional stability and lower polymerization shrinkage.

Addition curing silicones is widely used due to its high accuracy, good dimensional stability, good elastic properties, high tear strength, excellent flow, excellent recovery from deformation on removal, and short working and setting time. Furthermore, there is no by-products released during the polymerization process so it produces a highly stable impression. The set material is less rigid than polyether but stiffer than polysulfide. The impression can be poured multiple times and be kept with stable dimension for several weeks.[8]

One disadvantage of this material is that the setting reaction can be inhibited by sulfur or sulfur compound such as latex gloves or rubber dams which lead to produce inaccuracies impression and distortion model. Like condensation silicone, addition silicones are hydrophobic. Some polyvinylsiloxane materials have added surfactants to improve the wettability of the impression and gave them hydrophilic properties in which reduces the incidence of void or bubbles.[3, 8]

Polyvinylsiloxane is available in a range of viscosities, depending on the amount of the silica filler. The low viscosity materials has good flow and ability to capture fine detail of prepared tooth, including the margin. However, it has greater polymerization shrinkage during setting reaction and has inadequate dimensional stability. The medium body is commonly used as a monophase material. The heavy body or putty type has a higher viscosity and commonly used to support the light body material when taking the impressions.[9]

Polyether

Polyether impression material was developed in Germany in the mid-1960s. The base paste contains inert fillers and polymer chains which terminates with an amine group. The activator paste is an aromatic sulphonate ester. Polyether was characterized by excellent detailed reproduction, excellent dimensional stability and low shrinkage upon setting and no by product is formed. Due to the properties of high dimensional stability, plaster pouring can be delayed up to a week and it can be poured repeatedly.

It has good resistance to tearing but with high elastic modulus. Polyether is rigid and stiff when fully set which can cause problems when separating a stone cast from the impression. It also causes problems when removed from the mouth. Teeth with gingival recession resulting in large embrasures space as loss of periodontal support should be blocked with utility wax before impression making.[10]

Further advantages of polyether are hydrophilicity and good flow. It has low contact angle which is suitable for capturing a prepared tooth in presence of saliva or blood such as certain case with subgingival margin. It has short setting time (about 5 minutes) which is less than half the time required for polysulfide. The impression can not be contaminated by latex gloves. However, the moisture also can effect the dimensional expansion.[1-3]

Vinylpolyethersiloxane

Vinylpolyethersiloxane was commercially introduced in 2009. It is a formulation that combined properties of co-polymer of the polyvinylsiloxane and vinyl group of the polyether together. The purpose of the hybrid is to obtain the best features of each type of materials. The polyether component makes the material natural hydrophilicity with good flowability. The siloxane component provides dimensional stability and elastic recovery, facilitating easier intraoral impression removal than polyether.[11]

This material is available in various viscosities: heavy, medium and light body. Both single or multiple viscosity can be used but it should be applied with single impression technique. Accordijng to a study by Stober et a in year 2010, the accuracy of vinylpolysiloxane monophase impressions or dual viscosity impression did not significantly differ from polyether and polyvinylsiloxane impression. Hence, they concluded that vinylpolysiloxane displayed acceptable accuracy for clinical use.[12]

Impression technique

Impression technique can be categorized into two types: mono-phase and dual-phase technique which was based on the material used and the number of steps required.

Monophase

Monophase impression is performed in one single step by applying one viscosity of impression material, which is usually medium or regular body. Additional silicone and polyether are suitable for this technique as they have appropriate capacity for shear thinning and good accuracy. The advantages of a monophase method are easy and simple in technique, less chairside time and no unequal setting times of two materials. However, the accuracy is poor due to greater polymerization shrinkage. Therefore, monophase impression technique is least accurate when compared with the other types.[13] Another research by Millar BJ et al in year 1998 reported monophase impression produced more void than the two-phase type due to the relatively high viscosity and reduced flow.[14]

Dual phase

Dual phase technique uses different viscosity impression materials during impression taking and can be achieve in one or two steps. The one step double phase technique is executed by loading high viscosity material in a stock tray, while syringed the low viscosity material over the prepared tooth. Then seated the impression tray over the syringed material so that both materials can set together. This technique is easy, requires less chairside time and able to capture fine detail from the use of a low-viscosity material. However, it is difficult to control the putty material bulk, as well as the early setting of the light body material, resulting in surface defects and poor blending between the two. The heavy body material can displace the light body which affects in less accurate detail reproduction.

The two step double phase technique is achieve by loading putty in the impression tray first. Wait untill the first stage of impression has set then continued by syringing the low viscosity material then seating it back in the mouth in the same position before. This technique allows a controlled bulk of material that compensates for the contraction with minimal dimensional change. However, it takes extra chairside time and wastes material.[13, 15]

From the study in year 1988 , Craig RG reported that the accuracy of impression materials tested was affected more by the impression technique, rather than the material itself.[3] The effect of the impression technique on the accuracy of the stone dies is debatable. Some proposed that there is no significant differences in the accuracy between single step versus dual step putty reline impression technique. [16, 17] Others have claimed that single step technique produces inaccurate dies due to the uncontrolable bulk of the lower viscosity impression.[18, 19] This lower viscosity material could be washed out from the critical areas like finishing line of the abutment preparation. The high viscosity putty, which lacks the ability of fine detail reproduction, would then take the light body's place afterwards.

Sulcus width

For record subgingival margins, the soft tissue needs to be retracted and displaced adequately for the impression material to penetrate. Previous studies showed that the sulcular width should be at least 0.2 mm so that the set impression material does not tear or becomes distorted when removed from the sulcus.[20-22] The sulcular width rapidly reduces to less than 0.2 mm within 40 seconds after the removal of the retraction cord.[23] Hence, the use of materials that can penetrate into a sulci narrower than 0.2 mm should be considered when taking an impression of the subgingival margin. Nonetheless, the dentist should be quick and skillful in order to provide good impression taking.

Aimjirakul P et al (2003) and Laufer BZ et al (1996) both reviewed that polyether and polysulfide penetrated well into the stimulated and narrowest sulci. However, for the narrowest sulcular width, the penetration ability of polysulfide was greater than that of the silicones. None of the impression materials was suitable for 0.05 mm wide sulci because of the high prevalence of tears and the impression materials itself are inability to enter into the narrow sulci.[21, 24]

Penetration test

Various methods are available for assessing the viscoelastic properties. Shark fin test was introduced and developed by 3M-ESPE company for exhibit the flow properties of their polyether impression materials under pressure, in relation to clinically reliable impression taking.[25] This shark fin test demostrate by forcing the impression materials through a triangular v-shaped slit for reflected the material flow into the gingival sulcus.The resulting impression shape related as a shark fin shape as its given name. Good flow properties were supposed to result in high shark fin, which was obtained for the polyether products, and this interpreted as a marker for high clinical reliability during impression taking. This is applicable, especially with regards to the flow in narrow sulcus areas.[26] The test was limited to flow data only and cannot predict the dimensional stability, surface detail reproduction or hydrophilicity.[26, 27] Klettke T (2006), German MJ (2008), Lawson N. (2011) and Huettig F. (2018) used shark fin test model to compare three groups of elastomers. The result revealed that the highest fins were found in polyether more than vinylpolyethersiloxane and the lowest were found in polyvinylsiloxane.[27-30] It was concluded that polyether had the greatest penetrative ability to flow in narrow sulci among the other materials. However, this method was executed on solid specimens or specimens that were made from dry metal model, which cannot be implied to related clinical use. [27-30]

Later on, Aimjirakul P. in year 2003 modified the model to simulate the elasticity of the human gingiva. By means of assembling the plastic block that was fitted with stainless steel sheet. The stainless-steel sheet represented each width of the gingival sulcus; 0.2, 0.1 and 0.05 mm with the same depth at 3 mm. They were used to fabricate a simulated elastic sulcus made from highly purified agar for electrophoresis (Agarose S, Nippongene), which was done in an incubator (27± 2ºc and 100% humidity) that stimulated the humidity of human mouth. Four types of medium consistency elastomeric impression material were studied. The penetration length of each impression was measured by using a measuring microscope (MM-60, Nikon) and its associated data processor (DP-303, Nikon).[24] The result showed that Impregum F (polyether) had the greatest extension compared to all other materials and this was true for all width. The penetrative ability of elastomeric impression material was greater with wider sulci. No significant differences were found between the impression materials in the 0.05 mm sulcular width group. The experiment was more reliable due to the model which simulated the clinical condition of the gingival sulcus, with regard to elasticity and moisture. They stimulated sulcus with one elastic wall representing the gingiva and the other solid wall representing the tooth surface. However, the shape of the stimulating model was a square block, which did not relate to the shape of the tooth. Perhaps, the result may not be accurate.

The model was then developed to shape like a tooth preparation surrounded by different sulcus width e.g. the model by Finger WJ. et al in 2008.[31] They used cylindrical stainless steel, stimulating tooth preparation, for their experiment. The model reproduced the artificial gingival tissue which stimulated clinical conditions. One wall of cervices was represented the moist gingival tissue and the other was non-instrument and dry tooth surface. A sulcus model was useful for screening evaluation of elastomeric impression material's ability to penetrate into a narrow sulcus. The result indcated that polyether had the best penetrative ability.

CHAPTER 3
METHODOLOGY

Materials

The materials used in this experiment were as follows:

1. Polyether (Impregum™, 3M ESPE, Germany) 2 viscosities: medium body and light body
2. Additional curing silicone (Provil® novo, Heraesus Kulzer, Germany) 2 viscosities: medium body and light body
3. Polysulfide (Permlastic™, Kerr, Germany) 2 viscosities: regular body and light body
4. Vinylsiloxanether (Identium®, Kettenbach, Germany) 2 viscosity: medium body and light body

Table 2 Elastomeric impression materials tested

Type of material	Brand name	Lot No.
Polyether	Impregum™ Penta Soft, 3M ESPE	5486491
	Impregum™ Garant L DuoSoft, 3M ESPE	5459727
Additional curing silicone	Provil® novo Medium, Heraesus Kulzer	K010023
	Provil® novo Light, Heraesus Kulzer	K010024
Polysulfide	Permlastic™ Regular, Kerr	7127890
	Permlastic™ Light Bodied, Kerr	7190730
Vinylsiloxanether	Identium® Medium, Kettenbach	180221
	Identium® Light, Kettenbach	180801058

Determining the sample size

Six impressions were made from each impression material for the three different sulcular width groups. The total impression specimens was 72 samples.

Model construction

1. Screw the simulated sulcus stainless-steel cylinder diameter 10.4, 10.2 and 10.1 mm into the plastic block.

2. Pour 1% agar into the bottom of the plastic block in an incubator (27 ± 2^{o} c and 100% relative humidity). Wait 20 minutes for the agar was set. (Figure 2).

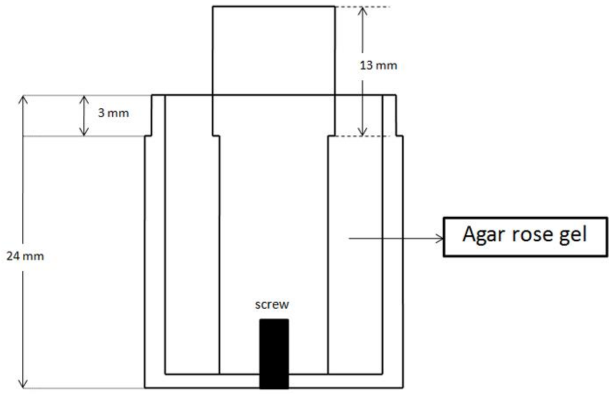


Figure 2 Agar rose gel in a plastic block with stainless steel simulated sulcus

3. Loosen the screw at the bottom of the block and gently separated the stainless-steel simulated sulcus from the plastic block, to construct simulating gingival tissue with 0.2, 0.1 and 0.05 mm wide sulcus (Figure 3).

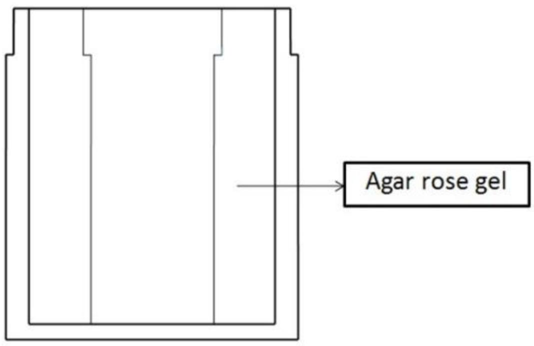


Figure 3 Simulating gingiva

4. Insert a simulating tooth (stainless-steel cylinder with 0.5 mm chamfer finishing line and slight convergence) into the simulated gingival sulcus, to construct the 3 mm depth gingival sulcus in three different width (0.2, 0.1 and 0.05 mm), with one wall representing the gingival and the stainless steel cylinder representing the tooth (Figure 4)

Figure 4 Simulated sulcus, with one wall representing the gingival and the stainless-steel cylinder representing the tooth

Methods

1. A single step double mix technique was applied for all the impression materials, which were the medium and light body.

2. All impressions were taken with the syringe-tray technique, by inserting the light body circumferentially into the gingival sulcus. The medium body was placed in the perforated stainless-steel tray (Figure 5) and immediately seated with light pressure. This process was done in the incubator at 27 ± 2 ºc and 100% humidity, by one operator only. A total of 72 impressions were made from the simulated models, with six impressions using each material for the three sulcular width groups.

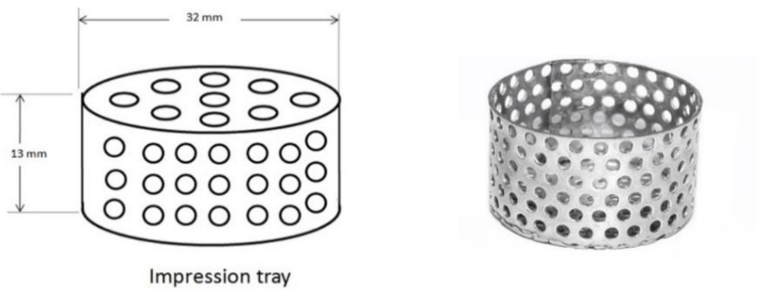


Figure 5 Perforated impression tray

3. The impressions were removed from the model and stored at room temperature for 30 minutes, following the recommended setting time by the manufacturer, before the impression extension were measured.

4. The extension of the impressions that penetrated into the stimulated sulcus were measured using four reference marks (Figure 6). The height of each extension was determined by using the stereo microscope (Olympus SZ61 steriomicroscope, Japan) and Image-Pro Plus image analysis software (Media Cybernetics, Inc., USA).

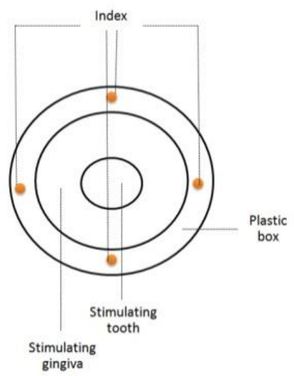


Figure 6 Four indices on the plastic block

Statistical analysis

The data of this study were analyzed by using the two-way anova analysis of variance for group comparison, and multiple comparison test analysis of variance for individual group comparisons, using SPSS version 20.0 (IBM SPSS Statistics for windows, version 20.0, NY, USA). The level of statistical significance (p-value) was set at $P \leq 0.05$.

CHAPTER 4
RESULTS

The result of impression extension were record by using the stereo microscope (Olympus SZ61 steriomicroscope (Japan) and Image-Pro Plus image analysis software (Media Cybernetics, Inc., USA). (Figure 7.) The mean average heights and the standard deviations are presented in Table 3. These data were then analyzed by the SPSS two-way ANOVA and Tukey HSD test.

Table 3 Mean values and Standard deviations of Impression Extension (mm)

Sulcular width (mm.)	Impregum™, 3M ESPE		Provil® novo, Heraeus Kulzer		Permlastic™, Kerr		Identium®, Kettenbach	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.2 mm	0.83^{a}	0.20	0.78^{a}	0.23	0.81^{a}	0.58	0.79^{a}	0.03
0.1 mm	0.64^{b}	0.11	0.49^{b}	0.11	0.57^{b}	0.10	0.51^{b}	0.05
0.05 mm	0.41^{c}	0.58	0.17^{d}	0.21	0.42^{c}	0.40	0.27^{f}	0.03

*Groups with the same superscripted letter indicated no significant differences between impression materials at $P < 0.05$. SD = standard deviation

The two-way ANOVA revealed siginifant differences among the impression materials, sucular widths, and their interactions ($p < 0.05$) (Table 4). Tukey HSD analysis showed that the penetration ability among the various type of impression materials was significant differences for four comparison, which were Provil novo - Permlastic, Provil novo - Impregum, Permlastic - Identium and Impregum - Identium (Table 5).

For the various sulcular width, all the paired comparisons were different. These diffferences were statistically significant (Table 6).

When considered the three sulcus depth, no statistically significant differences were found for any of the impression materials used. Regarding the 0.2 mm group, Impregum had the best reproducibility with the average extension height higher than that of Permlastic, Identium and Provil novo respectively.

In terms of the 0.1 mm group, Impregum was also the best at reproducing the extension height, followed by Permlastic, Identium and Provil respectively.

For the 0.05 mm sulcus width, Permlastic was considered as the best material, closely followed by Impregum, whilst Provil Novo offered the poorest mean extension height. However, the differences among Permlastic and Impregum material were not statistically significant (p value > 0.05). Permlastic, when compared with Identium and Provil, was statistically superior.

Impregum illustrated greater extension ability, comparing with the other three materials used in the study, especially for the 0.2 and 0.1 mm sulcus width, whereas Permlastic was the best for the 0.5 mm width.

Table 4 Summary of two-way ANOVA for extension of impression materials with varied sulcular width

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3.14[a]	11	0.29	66.45	.000	0.92
Intercept	22.55	1	22.55	5247.77	.000	0.99
TYPE	0.25	3	0.08	19.57	.000	0.49
SULCUS	2.78	2	1.39	323.77	.000	0.91
TYPE * SULCUS	0.10	6	0.02	4.13	.002	0.29
Error	0.26	60	0.00			
Total	25.95	72				
Corrected Total	3.4	71				

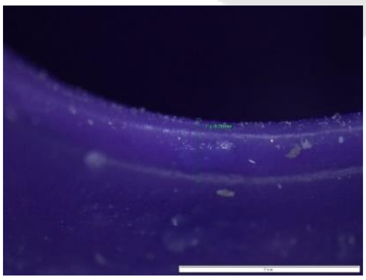
a. R Squared = 0.924 (Adjusted R Squared = 0.91)

Table 5 Results for the Tukey HSD test for multiple comparisons among the four impression materials

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Provil® novo	Permlastic™	-0.12*	0.02	0.00	-0.178	-0.06
	Impregum™	-0.15*	0.02	0.00	-0.20	-0.09
	Identium®	-0.04	0.02	0.23	-0.10	0.01
Permlastic™	Provil® novo	0.12*	0.02	0.00	0.06	0.18
	Impregum™	-0.03	0.02	0.58	-0.08	0.03
	Identium®	0.08*	0.02	0.00	0.02	0.13
Impregum™	Provil® novo	0.15*	0.02	0.00	0.09	0.20
	Permlastic™	0.03	0.02	0.58	-0.03	0.08
	Identium®	0.11*	0.02	0.00	0.05	0.16
Identium®	Provil® novo	0.04	0.02	0.23	-0.01	0.10
	Permlastic™	-0.08*	0.02	0.00	-0.13	-0.02
	Impregum™	-0.11*	0.02	0.00	-0.16	-0.05

Based on observed means. The error term is Mean Square (Error) = .004.

*. The mean difference is significant at the .05 level.



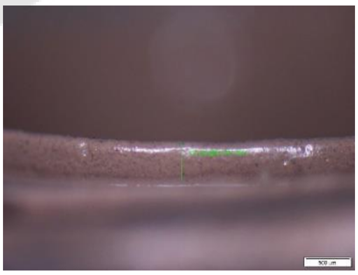


Figure 7 Figure 7.1 stereo microscope (Olympus SZ61 Steriomicroscope, Japan) picture demonstrating penetration of an impression material into the gingival sulcus.

Figure 7.2 Picture obtained from Image-Pro Plus image analysis software (Media Cybernetics, Inc., USA) demonstrating penetration of an impression material into the gingival sulcus.

CHAPTER 5
DISCUSSION

The null hypothesis that there is no significant difference on the penetrative ability of different elastomeric impression materials into the 3-dimensional gingival model is rejected. Both the sulcus width and the type of impression materials were important parameters for the penetrative ability.

Each type of impression materials differs in their structure and components, which leads to different penetrative ability. This study, as well as previous studies, showed that Impregum had the highest penetrative ability, under the experimental conditions. On the other hand, Provil had the lowest penetrative ability.

Polyether is hydrophilic by nature due to its carbonyl and ether functional groups that readily interacts with water molecules via hydrogen bonding.[1] This allows Impregum to work well in a wet environment such as the mucosal tissues. In order to get a good impression subgingivally, it is important to choose an impression material that works well with the presence of blood, saliva or gingival fluid. In the present study, Polyether had the highest penetrative extension.

This study depicted the penetrative ability by one impression technique only. However, the flowability rate of an impression material does not depend only on this property. Other vital factors include tear resistance, viscosity, hydrophilicity, good contact angel and various impression techniques.[32] According to a study by Herfort T (1978) , polyether and vinylpolyethersiloxane demonstrated higher tear strength than silicones, resulting in better flowability into the gingival sulcus.[30, 33] Many publication analyzing the contact angle of the elastomer impression material, stated that polyether and vinylpolyethersiloxane had smaller contact angle than silicone.[34-37] This indicated greater flowability and adaptability to contacting tooth surface. Van Krevelen DW et al (2009) and Rupp F et al (2005) reported that the chemical structure of polyether and vinylpolyethersiloxane were hydrophilic, whereas silicone was hydrophobic with surrounding hydrocarbon polymer that dislikes water.[37, 38] To counteract this hydrophobic characteristic, surfactant was added for improvement, but polyether was still naturally better. Therefore, additional silicone was shown to have the least flowability into the gingival sulcus, which was in accordance to the result of the present study. Further studies in different laboratory conditions are suggested for the benefits of selecting the most appropriate impression material in the clinical setting.

Apart from the impression material's properties, the width of the gingival sulcus also affects the penetrative ability. With reference to a study by Baharav et al. (1996), the critical sulcular width for the penetration of impression material should be 0.2 mm, with rapid closure of sulcus to less than 0.2 mm, within 40 seconds after removing the retraction cord.[21] We had applied these values in this study, by using 3 different sulcus width; 0.2 mm, 0.1 mm and 0.05 mm, as seen in Table 3. The results indicated diverse penetrative ability for different sulcular width. For 0.2 mm and 0.1 mm width, Impregum had the highest penetration. However, the differences found among all the impression materials were not statistically significant. This was in agreement with previous publication by Aimjirakul P et al. (2003). Regarding the sulcular width of 0.05 mm, all the material was not able to capture the details well enough and their differences were statistically significant. Surflex F polysulfide was superior to silicones under the same conditions, since it had greater tear strength and permanent set.[24] It was expected to be deformed rather than be torn, demonstrating a completely set but distorted impression. A low viscosity material can penetrate well in an abutment without undercut. The specimens used in this study had no undercut and were hydrophillic, resulting in high penetration value. The result confirmed the conclusion of Craig RG's study that Permlastic penetrated better than Impregum in a sulcus with 0.1 mm width.[39]

In contrast, polyether can be stiff when fully set, making it difficult to remove, especially in area with undercuts or narrow sulcus.[1, 3, 10] Breakages of both the impression and the dental cast can occur as a consequent. This supports the result of the study that in a 0.05 mm sulcus, polyether had lower penetrative ability than polysulfide but the difference was not statistically significant. In the field of prosthetic dentistry, polysulfide is not widely used for dental crown fabrication due to its low dimensional stability, long setting time, unpleasant odor, strong bitter taste, staining and handling difficultly.[1-3]

The American Dental Association had no set regulations on how to measure the penetrative ability for non-aqueous, elastomeric dental impression materials.[9] Several models were invented by researchers as shown in the literature to test this ability of the elastomeric material. The present study had developed and utilized previous models such as the shark fin test which is a 2-dimensional linear model, constructed in a solid condition unlike the oral cavity.[24, 26-30] A new model was designed in an attempt to simulate a clinical situation of a tooth preparation with one wall representing the gingival sulcus and a stainless-steel cylinder representing the tooth, with 0.5 mm chamfer finishing line and slight convergence. The simulation sulcus innovative model was a good replication of the oral condition which was suitable for this laboratory study.

From a clinical point of view, it is difficult to fabricate a good impression of a narrow gingival sulcus, when used with an impression cord or inappropriate impression material. This in vitro study demonstrated that polyether and polysulfide had high ability to penetrate in a narrow sulcus. The results may be beneficial in clinical situations which require multiple preparations, when a retraction cord cannot be removed in time and where subgingival margin is presented. However, it is greatly important to note that a proper impression should always be checked by the three compositions, which are the impression itself, abutment condition and gingival management.

Conclusions

1. Within the limitations of the present study, we conclude that different elastomeric impression materials had the ability to penetrate into the 3-dimensional gingival model differently, depending on the width of the gingival sulcus.
2. The penetrative ability of different elastomeric impression materials became greater with wider sulcus.
3. For gingival width less than 0.05 mm, none of the material was suitable for obtaining clinically acceptable impressions.

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APPENDIX

Table 6 Results for the Tukey HSD test for multiple comparisons of the three different sulcus widths

(I) SULCUS	(J) SULCUS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0.2 mm	0.1 mm	0.25*	0.02	0.00	0.20	0.29
	0.05 mm	0.48*	0.02	0.00	0.43	0.53
0.1 mm	0.2 mm	-0.25*	0.02	0.00	-0.29	-0.20
	0.05 mm	0.23*	0.02	0.00	0.19	0.28
0.05 mm	0.2 mm	-0.48*	0.02	0.00	-0.53	-0.44
	0.1 mm	-0.23*	0.02	0.00	-0.28	-0.19

Based on observed means. The error term is Mean Square (Error) = .004.

*. The mean difference is significant at the .05 level.

Test of Normality

Table 7 Results for the Kolmogorov-Smirnov Test for data normality

Kolmogorov-Smirnov		
Statistic	df	Sig
0.11	24	0.20*

*. This is a lower bound of the true significance.

Test of Homogeneity of Variances

Table 8 Results for the Levene's test for homogeneity of variance

Levene Statistic	df1	df2	Sig
2.355	11	60	0.017

Table 9 Results for the Dunnett T3 test for multiple comparisons among the four impression materials, in a 0.2 mm gingival sulcus

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Provil® novo	Permlastic™	-0.02	0.02	0.78	-0.08	0.04
	Impregum™	-0.03	0.01	0.05	-0.06	0.00
	Identium®	0.01	0.01	0.97	-0.04	0.05
Permlastic™	Provil® novo	0.02	0.02	0.72	-0.03	0.07
	Impregum™	-0.01	0.02	0.96	-0.07	0.04
	Identium®	0.03	0.02	0.53	-0.03	0.09
Impregum™	Provil® novo	0.03	0.01	0.05	-0.00	0.06
	Permlastic™	0.01	0.02	0.96	-0.04	0.07
	Identium®	0.04	0.01	0.09	-0.00	0.09
Identium®	Provil® novo	-0.01	0.01	0.97	-0.06	0.03
	Permlastic™	-0.03	0.02	0.53	-0.09	0.03
	Impregum™	-0.04	0.01	0.09	-0.09	0.00

Table 10 Results for the Dunnett T3 test for multiple comparisons among the four impression materials, in a 0.1 mm gingival sulcus

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Provil® novo	Permlastic™	-0.09	0.06	0.68	-0.29	0.12
	Impregum™	-.016	0.06	0.17	-0.37	0.05
	Identium®	-0.03	0.05	0.99	-0.21	0.15
Permlastic™	Provil® novo	0.09	0.06	0.68	-0.12	0.29
	Impregum™	-0.07	0.06	0.82	-0.27	0.13

Table 10 Results for the Dunnett T3 test for multiple comparisons among the four impression materials, in a 0.1 mm gingival sulcus (continued)

Impregum™	Identium®	0.06	0.05	0.75	-0.10	0.23
	Provil® novo	0.16	0.06	0.17	-0.05	0.37
	Permlastic™	0.07	0.06	0.82	-0.13	0.27
Identium®	Identium®	0.13	0.05	0.15	-0.04	0.31
	Provil® novo	0.03	0.05	0.99	-0.16	0.21
	Permlastic™	-0.06	0.05	0.75	-0.23	0.10
	Impregum™	-0.13	0.05	0.15	-0.31	0.41

Table 11 Results for the Dunnett T3 test for multiple comparisons among the four impression materials, in a 0.05 mm gingival sulcus

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Permlastic™	-0.25*	0.02	0.00	-0.32	-0.19
	Impregum™	-0.24*	0.02	0.00	-0.33	-0.15
	Identium®	-0.10*	0.02	0.01	-0.15	-0.05
Permlastic™	Provil® novo	0.25*	0.02	0.00	0.19	0.32
	Impregum™	0.01	0.02	0.99	-0.08	0.11
	Identium®	0.15*	0.02	0.00	0.08	0.22
Impregum™	Provil® novo	0.24*	0.02	0.00	0.15	0.33
	Permlastic™	-0.01	0.02	0.99	-0.11	0.08
	Identium®	0.14*	0.02	0.01	0.05	0.23
Identium®	Provil® novo	0.10*	0.02	0.01	0.05	0.15
	Permlastic™	-0.15*	0.02	0.00	-0.22	-0.08
	Impregum™	-0.14*	0.02	0.01	-0.23	-0.05

*. The mean difference is significant at the .05 level

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