ACCURACY OF POLYVINYL SILOXANE IMPRESSION MATERIAL WITH DIFFERENT INTER IMPLANT ANGULATION

By

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DEDICATION

I would like to dedicate this work to all Iraqi martyrs; To my dearest family, my grandparents, my mother and my father for taking care of me since my childhood and whose good examples have taught me to work hard for the things that I aspire to achieve, may Allah bless their life, in addition, to my brothers and sisters, Dr. Ahmed, Dr. Amina, Dr. Haider, Dr. Asma, Eng. Alla, and Eng. Murtadha, whose continuous love and prayers have had profound impact on success in my life. I pray to almighty GOD to protect them and bless them forever.

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ABBREVIATIONS

PVS Polyvinyl siloxane

PE Polyether

ADA The American Dental Association

KETEPATAN BAHAN IMPRESI ‘POLYVINYL SILOXANE’ DENGAN SUDUT ANTARA IMPLAN YANG BERBEZA

ABSTRAK

Persoalan jika keanjalan bahan impresi, sudut antara implan, dan gabungan faktor-faktor ini memberi kesan kepada ketepatan impresi implan telah dibangkitkan. ‘Polivinyl siloxane’ (PVS) disyorkan sebagai bahan impresi untuk kegunaan klinikal berikutan ciri-cirinya yang bersesuaian, justeru telah dipilih untuk kajian ini. Objektif kajian ini adalah untuk menentukan modulus keanjalan dua bahan PVS (‘medium body’), membandingkan kesan gabungan keanjalan bahan dan sudut antara analog implan (0 °, 5 °, 10 °, dan 15 °) pada ketepatan impresi, di samping menentukan kesan keanjalan berbeza dan perbezaan sudut secara berasingan ke atas ketepatan impresi. Ujian tegangan telah dijalankan untuk membandingkan modulus keanjalan ‘Young’ antara bahan PVS Aquasil ‘medium body’ (‘Aquasil’) dan bahan PVS Virtual ‘medium body’ ('Virtual'). Empat blok induk akrilik telah dihasilkan dengan dua analog implan dalam setiap blok: satu analog diletakkan pada sudut 0° (implan rujukan) manakala yang kedua diletakkan pada 0°, 5°, 10°, dan 15° setiap blok. Enam puluh empat impresi telah diambil, 16 impresi untuk setiap satu daripada empat blok induk, dengan lapan dibuat menggunakan bahan ‘Aquasil’ dan lapan lagi dengan bahan ‘Virtual’. Semua impresi telah dilakukan menggunakan teknik

‘closed tray’. Blok kajian telah disediakan menggunakan ‘die-hard stone’. Ketepatan impresi ditentukan dengan membandingkan perbezaan ukuran dimensi linear (dalam μm) blok kajian relatif kepada blok induk, menggunakan projektor profil (pembesaran asal × 10). Setiap ukuran diulang lima kali dan nilai purata telah diambil. Data dianalisis menggunakan IBM SPSS v.22 (SPSS Inc, Chicago) dengan tahap kepentingan statistik (p) ditetapkan pada <0.05. Hasil kajian menunjukkan bahawa bahan ‘Aquasil’ adalah lebih anjal daripada bahan ‘Virtual’ (modulus keanjalan masing-masing 4.4 Mpa (SD 0.33 Mpa) dan 8.3 Mpa (SD 0.38 Mpa). Hasil kajian juga menunjukkan bahawa gabungan keanjalan bahan dan sudut antara implan mempunyai kesan ke atas ketepatan impresi ($p = 0.03$). Tanpa mengambil kita sudut antara implant, bahan ‘Virtual’ menghasilkan impresi yang lebih tepat berbanding bahan ‘Aquasil’, bagaimanapun perbezaan ini tidak signifikan ($p = 0.330$). Sudut antara implan pula memberi kesan signifikan ke atas ketepatan impresi tanpa mengambil kira faktor keanjalan bahan ($p = 0.027$). Analis ‘post-hoc’ menggunakan prosedur Tamhane menunjukkan perbezaan yang signifikan antara pasangan analog bersudut 0 º- 10 º dan 0 º- 15 º. Kesimpulannya, kajian ini menunjukkan bahawa interaksi antara keanjalan bahan PVS dan sudut antara implan yang mencapah menjejaskan ketepatan impresi. Tanpa mengambil kira keanjalan bahan, sudut antara implan juga mempunyai kesan ke atas ketepatan impresi.

ACCURACY OF POLYVINYL SILOXANE IMPRESSION MATERIAL WITH DIFFERENT INTER IMPLANT ANGULATION

ABSTRACT

Questions have been raised about whether the elasticity of the impression material, the inter-implant angulation, and the combination of these factors affect the impression accuracy of the implant impression. Given its favorable properties, Polyvinyl Siloxane (PVS) has been recommended as an impression material for clinical use, and thus selected for this study. The objectives of this study were to determine the modulus of elasticity of two PVS (medium body) impression materials, to compare the combined effects of impression material elasticity and dental implant analog angulation (0°, 5°, 10°, and 15°) on the accuracy of the impression, to compare the effect of impression material elasticity on the accuracy of the dental implant analog impression regardless of the inter-implant angulation and to compare the effect of dental implant analog angulation regardless of the material elasticity on the accuracy of the impression. Tensile tests were done to compare the modulus of elasticity between the medium body Aquasil PVS material (‘Aquasil’) and the medium body Virtual PVS material (‘Virtual’). Four block shaped acrylic master models were fabricated with two implant analogs in each: the first was placed at 0° angulation (reference implant) while the second placed at 0°, 5°, 10°, and 15°

respectively. Sixty-four impressions were taken, 16 impressions for each of the four master casts, eight of them made using Aquasil impression material and the other eight impressions with Virtual impression material. All impressions were obtained using the closed tray technique. Study casts were fabricated with high-strength low-expansion die-hard stone. The impression accuracy was determined by comparing the difference in linear measurement of the study casts relative to the master casts in µm, measured with a profile projector (original magnification ×10). Each measurement was repeated five times and an average was calculated. The data were analyzed with IBM SPSS v.22 (SPSS Inc, Chicago) with the level of statistical significance (p) set at <0.05. The results showed that Aquasil medium body impression material is more elastic than the Virtual medium body impression material (modulus of elasticity 4.4 Mpa (SD 0.33 Mpa) and 8.3 Mpa (SD 0.38 Mpa) respectively. The result also suggested that material elasticity and inter-implant angulation had a combined effect on the accuracy of the implant impression ($p = 0.03$). Further, Virtual (medium body) impression material had less discrepancy than Aquasil (medium body) impression material, regardless of the inter-implant angulation. However, the difference was not statistically significant ($p = 0.330$). The inter-implant angulations were significantly associated with the impression accuracy ($p = 0.027$) regardless of the elasticity of the material. Post-hoc analysis using Tamhane's procedure showed a significant difference between angulation pairs of 0 º- 10 º and 0 º- 15º

In conclusion the study demonstrated that the interaction between PVS impression materials of different elasticity (Virtual and Aquasil medium body) and the inter implant angulation of the analogs placed divergently produced a significant adverse effect on the impression accuracy. Regardless of material elasticity, the angulation of the implant analogs also adversely affects the impression accuracy.

CHAPTER ONE

INTRODUCTION

1 Introduction

An accurate impression is important for dental implants because prosthesis should be fabricated such that it does not confer any stress to the inserted implant when completely seated (Adell et al., 1981). Oral rehabilitation of partially and completely edentulous patients with dental implants is currently routine procedure, and clinical studies have proven the longitudinal effectiveness of this treatment modality (Ravald et. al., 2013). As endosseous implants are functionally ankylosed with direct contact to the bone, they lack the inherent mobility of the periodontal ligament (Ravald et. al., 2013). Hence, they cannot accommodate distortions or misfit at the implant-abutment interface. Screw loosening and/or fracture, implant fractures, and prosthetic-component strain and fracture have been related to prosthesis misfit. It is still unclear what degree of prosthesis misfit will lead to biologic or technical complications.

The clinical fit of implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and cast fabrication (Taylor and Agar, 2002).

Implant impression materials should have the following characteristics: have adequate strength to avoid breaking or tearing upon removal from the mouth; and possess acceptable elasticity and dimensional stability without permanent deformation after strain to facilitate accurate cast production (Braden and Eliot, 1966). At present, the most popular impression material in dental implant preparation is polyvinyl siloxane (PVS) because of its good handling characteristics, physical properties, and dimensional stability (Manappallil, 2010). PVS impression materials, which have been available in the market since the mid-1970s, can be applied to various indirect procedures in prosthodontics and restorative dentistry (Mandikos, 1998). Although the effects of elasticity on implant accuracy have been tested, the accuracy of dental implant impressions using PVS, particularly with distinct stiffness, has not been well established (Liou et al., 1993). Addition silicones have higher modulus of elasticity than other elastomeric impression materials. These materials are advantageous over earlier condensation silicones because they have less dimensional change and higher elastic recovery (McCabe and Walls, 2008). Previous studies have proposed that set impression can be easily removed when addition silicone materials are used because of their more favorable modulus of elasticity (Chai et al., 1998). Thus, PVS could reduce the permanent deformation of an impression material when the impression coping together with the impression is removed from the internally connected implants. High-level stress has been speculated to occur between the impression copings and impression materials when the impressions with their copings are removed from the internally connected implants (Vigolo et al., 2004).

Many studies have compared the impression accuracies of PVS and PE, but the accuracies of different bands of PVS have not been determined. Reddy (2013) examined the dimensional accuracies of PVS- and PE-based implant impressions and found no significant difference in the dimensional accuracy of the resultant casts constructed using closed-tray technique. PVS was reported to be more dimensionally stable than PE and was characterized by excellent dimensional accuracy and long-term dimensional stability.

Most studies on dental implant impressions have evaluated the improvement of impression accuracy using parallel implants with 0° angulation, while several studies have investigated the effect of nonparallel implants with angulations of different degrees on the final precision of the impression (Carr et al., 1996). The increasing divergence or convergence of implants had been reported to have detrimental effects on impression accuracy (Carr, 1996; Assuncão et al., 2004), whereas some other studies reported no angulation effect on the accuracy (Choi et al., 2007; Conrad et al., 2007).

1.1 Rationale of the Study

The suitability of a recommended material for implant impressions and the effects of implant angulation on the accuracy of the working cast remain debatable. Thus, evaluating the effect of impression materials with different elasticity and implant angulations on the accuracy of the impression is important (Cehreli et al., 2006).

1.2 General Objective

To compare the impression accuracy of dental implants analogs placed at different angulations taken using PVS (medium body) impression materials of different elasticity, employing the close tray technique.

1.3 Specific Objectives

i. To determine the modulus of elasticity of two PVS (medium body) impression materials.

ii. To compare the combined effects of impression material elasticity and dental implant analog angulation (0°, 5°, 10°, and 15°) on the accuracy of the impression.

iii. To compare the effect of impression material elasticity on the accuracy of the dental implant analog impression.

iv. To compare the effect of dental implant analog angulation (0°, 5°, 10°, and 15°) on the accuracy of the impression.

1.4 Hypotheses

ii. The combination of material elasticity and dental implant analog angulation (0°, 5°, 10°, and 15°) significantly affects the accuracy of the impression.

iii. The impression material elasticity significantly affects the accuracy of the dental implant analog impression.

iv. The dental implant analog angulation (0°, 5°, 10°, and 15°) significantly affects the accuracy of the impression.

1.6 Significance of the Study

The knowledge on the influence of PVS impression material elasticity and the effects of the implant angulation on the impression accuracy will be useful for clinicians in selecting a plan that will maximize the success rate of the implant treatment for the patients.

CHAPTER TWO

LITERATURE REVIEW

2. Literature Review

2.1 Impression Materials

In general, the accuracy of any implant cast depends on some basic factors which include the technique of implant impression, the type of impression material and, the angulation of the implant. A definitive clinical goal ought to be to fabricate prosthesis that seats passively onto the implants. Several questions have been raised, such as whether the difference in the elasticity of two PVS impression materials (i.e., Virtual and Aquasil medium bodies) affects the impression accuracy of the dental implant; whether the angulated dental implant affects the accuracy of the implant impression; and whether the interaction between material and angulation significantly affects the implant impression (Vigolo, et. al. 2003)

Pfaff, a German dentist, was the first to use sectional wax impressions of the mouth to prepare plaster models in 1756 (Peyton, 1968), during which wax and plaster were the common dental materials. Waxes, plaster models, and metal dice were used for impressions in England in 1840 (Perkins, 1966). Plaster was used for mouth impressions in 1844. In 1857, Stent developed a modeling compound that was used as an impression material in 1874. Agar–agar compounds or reversible hydrocolloids were developed by Poller, who was granted a British patent for this material in 1925. This gel technique is initially complicated by the supposedly required special heaters and syringes, which are subsequently discarded (Bergman, 1980). Poller sold the patent rights for its dental use to the De Trey brothers of Zurich, Switzerland. The De Trey brothers marketed a modification of this material under the trade name “Dentocoll.”

After American patents have been granted, numerous materials with natures similar to that of Dentocoll have been developed, among which the most essential ingredient was agar–agar (Perkins, 1966). In 1937, Sears used agar–agar for crown and bridgework, whereas Paffenbarger proposed a specification in 1940 (Paffenbarger, 1974).

An alginate-based impression material introduced before World War II attracted much interest during the aforementioned period when agar supplies were terminated (Perkins, 1966). With the continuous development of alginate impression materials, several scholars have suggested the application of these materials for inlay, crown, and bridge procedures (Fusayama, 1957; Skinner et al., 1950; Skinner and Pomes, 1947).

2.2 Development of Elastomers

Elastomeric impression materials are widely used in dental surgery. These materials have good tear resistance and dimensional stability (Cartmen, 2010). Elastomeric materials become flexible cross-linked polymers when set. Except for the preparation of study models, elastomeric impression materials dominate the market mainly because of their higher accuracy, long-term dimensional stability, and ability to record details compared with hydrocolloid materials. Polysulfides were the first elastomeric impression materials, followed by condensation silicones, PEs, and addition silicones (Powers and Wataha, 2013). Elastomeric impression materials are supplied in two components, namely, base and catalyst pastes (or liquid), which are mixed prior to impression creation. These materials are often produced with several consistencies, including extra low, low, medium, heavy, and putty, based on the increasing filler content (Anusavice et al., 2013).

An elastomer is a polymer with rubber-like properties (i.e., natural or synthetic rubber). Dental impression elastomers cure (vulcanize) from viscous fluids to elastic solids at room temperature. These materials are high polymers characterized by kinked or coiled macromolecules, which straighten under a load to produce very long extensions. The molecules tend to revert to their initial configuration upon removal of the deforming force. Four types of elastomeric impression materials are currently available in the dental industry. These materials include polysulfides, condensation-curing silicones, newly developed addition-curing silicones, and PEs (McCabe and Walls, 2008). Various rubber-like impression materials, which were described as non-aqueous elastomeric impression materials, rubber-base materials, and elastomers, have also been developed. These materials set via polymerization reactions and are more stable than hydrocolloid materials (Gladwin and Bagby, 2009). Elastomeric materials are not affected by atmospheric changes and become more elastic and rubber-like when set, which is important during their removal from the oral cavity such that little or no distortion or tearing will occur (Dietz-Bourguignon, 2006). Polysulfide rubbers were introduced for industrial application in 1929.

Patric developed liquid polymers in 1943 in the USA when he explored an anti-freeze liquid in Thiokol Laboratories Inc. (NJ, USA) (Kinghorn, 1957). These polymers have been extensively used in military applications but not in the general industry, until after World War II (Jorczak et al., 1951). Liquid polymers were introduced to dentistry in the 1950s (Bell et al., 1975). Similarly, silicone rubbers were also developed for industrial use but not for dentistry until the late 1950s.

Polysulfide-based impression materials were first developed and successfully modified for clinical application than silicone-based materials (Asgar, 1971). The first dental silicone was set through a condensation–polymerization reaction, with hydrogen as a by-product, resulting in bubble production in stone dice (Peyton, 1965). In the 1960s, materials with a change-setting reaction were introduced, in which methyl or ethyl alcohol was the by-product, thereby preventing bubble production in stone dice (Brown, 1981; Peyton, 1965).

However, developed silicones have inferior dimensional stability because of their volatile by-product production (Braden, 1975; Phillips, 1973). These materials are currently known as Type 1 silicone or condensation-curing silicones.

Another type of silicone that sets through an addition–polymerization reaction has been developed. No by-products are produced by this reaction process. These materials, which were originally developed for the Apollo space program, are known as Type 2 silicone or addition-curing silicones (Brown, 1981). The elastomeric impression materials used in dentistry are mostly derived from systems originally intended for industrial applications (Figure2. 1).

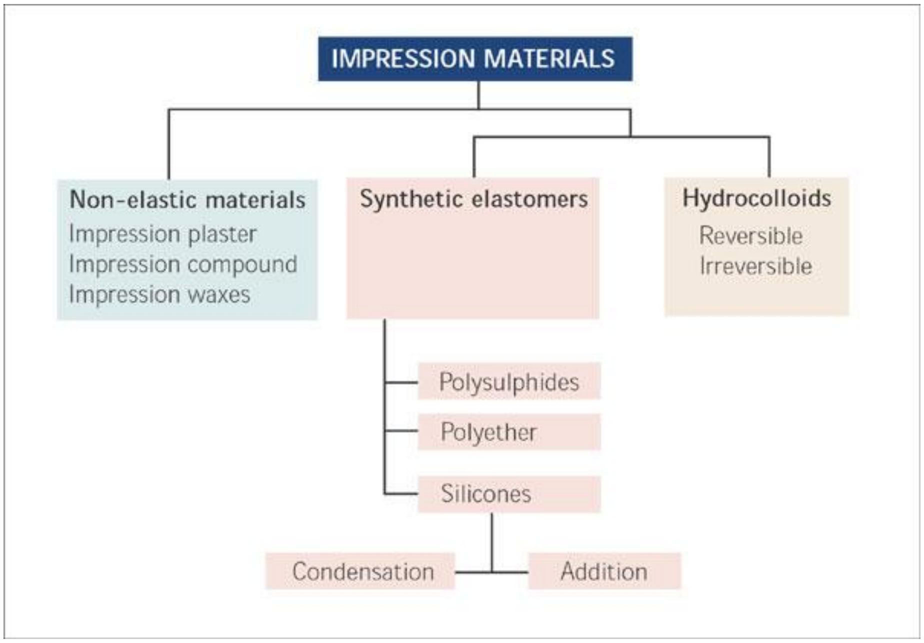

Figure 2.1. Impression materials calssification (Wassell et al.,2002)

2.2 General Requirements of a Dental Impression Material

The impression process is crucial for impression accuracy, and the impression material is another factor related to the final cast accuracy.

An extensive variety of impression materials are available because manufacturers produce more than one type of these materials. Anusavice (2013) and Powers and Wataha (2013) provided several specifications for acceptable impression materials:

1- pleasant odor, test, and color

2- irritant-constituent- or toxic- free

3- adequate shelf life

4- economically consistent with the results obtained

5- easy to use with minimum equipment

6- setting characteristics that satisfy clinical requirements

7- satisfactory consistency and texture

8- elastic properties without causing permanent deformation after strain

9- adequate strength to prevent breaking or tearing on removal

10- dimensionally stable over temperature and humidity

11- accuracy in clinical use

12- compatible with cast and die materials, and

13- no significant degradation of properties as a result of disinfection

Hardness is also very important for impression materials. Barrett et al. (1993) investigated the use of high-consistency impression material using a low-consistency wash. In this study, the following impression materials were compared: irreversible hydrocolloid, impression plaster, PE, and PVS (heavy/light body). Results showed no significant differences among the materials.

Walker et al. (2008) investigated the implant impression accuracy as a function of impression technique and combination of material viscosity. An indirect closed-tray technique was used versus the direct closed-tray technique, and a heavy or medium body around the impression copings was used in conjunction with a medium-body material in the impression tray. Accuracy was found to be unaffected by the viscosity of the impression material, and a stiffer material did not contribute to the accuracy of the results.

2.4 PVS Impression Materials

Addition silicone impression materials [also known as PVS or vinyl polysiloxane (VPS)] have been developed as alternative to polysulfides and condensation silicones (Powers and Wataha., 2013). Compared with condensation silicones, addition silicones are based on the addition–polymerization reaction between divinylpolysiloxane and polymethylhydrosilixane with a platinum salt as the catalyst (Anusavice, 2013). PVS impression materials undergo the polymerization reaction of chain lengthening (called the addition reaction) and cross-linking with reactive vinyl groups to produce a stable silicone rubber. The addition reaction does not produce a low-molecular weight by-product that can evaporate and cause shrinkage similar to the condensation silicones. PVS exhibits the least dimensional change (0.05%) on setting among elastomeric and hydrocolloid impression materials. PVS has high elastic recovery after removal from undercuts, as well as high tearing resistance (Hatrick et al., 2011). PVS materials have high accuracy, do not shrink, are dimensionally stable, and have no objectionable odor or taste. These materials are easier to manipulate than other materials (Dietz–Bourguignon, 2006).

PVS impression materials have been widely accepted since their introduction in the 1970s. PVS materials have many applications in implant dentistry, fixed prosthodontics, removable prosthodontics, and operative dentistry. These materials are produced in two paste forms, as a base and an accelerator, which facilitate the convenient spatulation or auto-dispensing of PVS from a dual cartridge or the mixing of PVS in equivalent amounts. PVS materials are highly accepted by dentists and patients because they are odorless, clean, and tasteless (Chee et al., 1992).

2.4.1 Chemistry

PVS materials undergo addition reactions, in which termination occurs to the base polymer with the groups of vinyl and cross-linked with silane (hydride groups). This reaction is activated by a platinum salt.

A PVS material is modified original condensation silicone. Both materials are based on polydimethylsiloxane polymer but with distinct existent terminal groups based on the differences of their curing reactions (van Noort, 1994). Polyvinyls have significantly improved dimensional stability and differ in setting reactions from that of the condensation-curing silicones, so PVS should be classified as another category of materials (Shillingburg et al., 1981).

A base material contains polymethyl hydrogen siloxane copolymer, a polymer with low-molecular mass and silane terminal groups. An accelerator material, such as vinyl-terminated polydimethyl siloxane, is a polymer with low to moderate molecular mass and contains vinyl-terminal groups (van Noort, 1994;

Craig, 1993). Moreover, the accelerator material contains chloroplatinic acid as a homogeneous metal complex catalyst (Williams and Craig, 1988; O'Brien et al., 1989). An addition reaction occurs between the vinyl groups and silane upon mixing (Figure 1). Minimum dimensional changes occur and no by-product is produced during polymerization. Hydrogen gas bubbles are formed on the surface of the gypsum dice poured directly from the PVS impression (Chee et al., 1992; Williams and Craig, 1988). A side reaction of hydrides on the base polymer can produce hydrogen gas if residual silanol groups or moisture are available. Manufacturers have eliminated the possibility of this side reaction through suitable purification and accurate proportioning of materials and by adding palladium to the paste as a hydrogen absorber (Craig et al., 1996; O'Brien et al., 1989) (Figure 2.2).

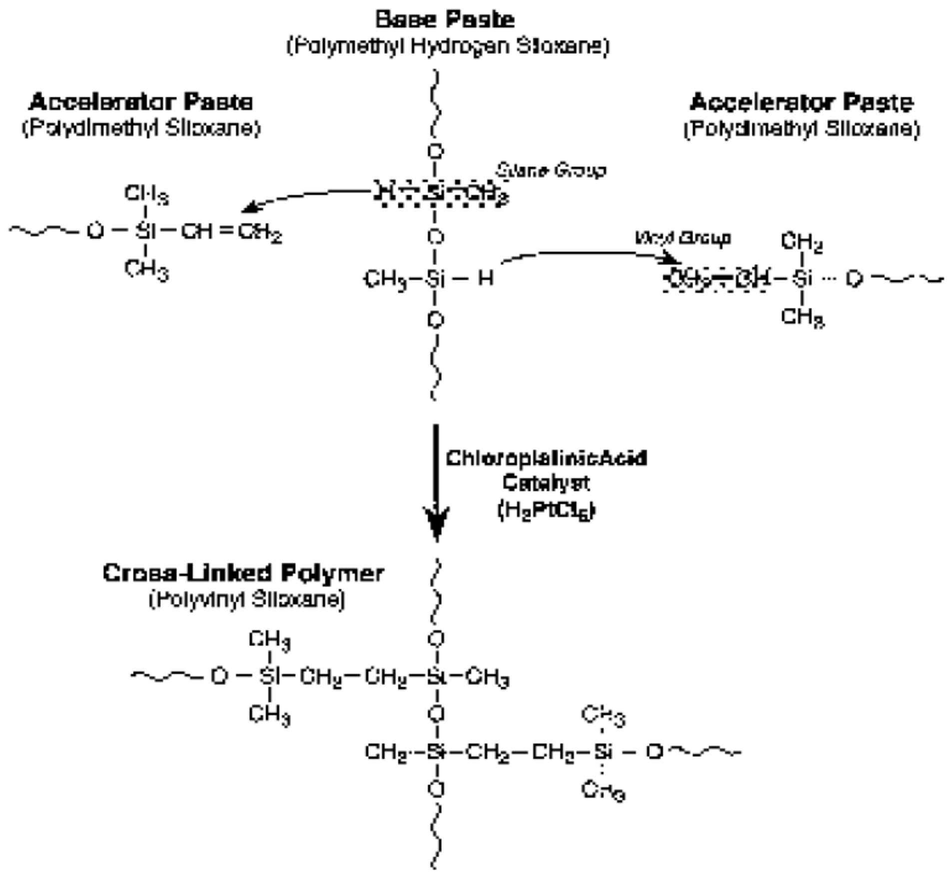

Figure 2.2 Chemical reactions to produce PVS (Mandikos, 1998)

2.4.2 Properties of PVS Impression Materials

2.4.2. 1 Viscosity

The manufactured material comprises short-silicone rubber molecules with several reactive groups on each molecule. Fillers are added to achieve suitable viscosity, and a catalyst is also added as activator. Addition silicones are manufactured with five viscosities: light body, medium body, heavy body, monophase, and putty. Each type of viscous silicone is in the form of two different colored pastes. Pastes (except for putty) are mixed similar to polysulfide materials. Addition silicones are also provided in double-barreled cartridges for use in an "automix gun." An automix system forces two pastes through a tip, which contains a spiral-shaped "baffle." In the tip, the baffle causes the material to swirl around and flow in a turbulent manner to mix the two pastes. A second smaller tip, which may be added to the main tip, is designed to intraorally dispense the impression material.

An automix system is very popular and has been adapted for other types of dental materials, such as acrylic resins for temporary crowns and bridges (Gladwin and Bagby, 2009).

PVS materials are available from very low (for pouring, syringe use, or wash use) viscosity, to medium, high, and very high viscosities. The viscosity of PVS increases with the filler content.

Viscosity is also affected by the shear force applied on the material. The relative viscosities of mixed base and catalyst pastes decrease in response to high shear stresses. This effect is termed as shear thinning. Thus, a medium-body impression material can possess sufficient viscosity to avoid excess flow if loaded into an impression tray. However, the material can also exhibit an apparently lowered viscosity, which is suitable for intra-sulcular impressions, when expressed on the impression syringe tip (Chai et al., 1994; Craig, 1993). The effect of shear thinning is more pronounced in materials with higher viscosity. This phenomenon is possibly due to the extremely small filler particle sizes. Thixotropy is the property of some gels to liquefy when subjected to vibrating forces (e.g., ultrasonic waves) and solidify when left to stand again

(Barnes. 1997). PVS materials behave similarly, but its classification as thixotropic materials has not been sufficiently investigated.

2.4.2.2 Working and Setting Times

A retarder is often supplied to extend the working and setting times. Addition silicones have faster working and setting times than polysulfide materials. The materials have excellent elasticity and show very low dimensional shrinkage during storage. Therefore, addition silicones can safely be poured or subsequently sent to a dental laboratory.

However, addition silicones are highly rigid. Thus, removing the impression around the undercuts is difficult as indicated by their low elasticity value. Addition silicones have similar tear strength to condensation silicones but lower than polysulfides (Powers and Wataha, 2013; O'Brien, 2008).

Working time begins at the start of mixing and ends before the elastic properties develop. The working time should be higher than the time required for mixing, filling the syringe and/or tray, injecting the material on tooth preparations, and setting the tray.

Setting time is the time elapsed from the beginning of mixing until the curing process sufficiently advances to allow the removal of the impression from the mouth without distortion. However, polymerization may continue for a considerable time after setting. An increase in temperature accelerates the polymerization of all elastomeric impression materials. Therefore, the effect of temperature on the working and setting times should be considered.

The working and setting times decrease as the filler content in the materials increases. Altering the base/catalyst ratio will change the curing rate of these impression materials. The presence of high amount of base materials in the mixture generally prolongs the working and setting times (Anusavice et al., 2013).

Modern PVS materials have working and setting times of 2 and 6 min (with slight variation), respectively (Hatrick et al., 2011, Chee et al., 1992). These times may be adequate or optimal. Some conditions occasionally require extended working times, and techniques that alter the working and setting times have been reported. The proportion of catalyst should not be altered because it could lead to variable results and facilitate the side reaction that produces hydrogen gas.

Several manufacturers supply a retarder that can be incorporated into the mix to prolong working time without compromising other properties (Chee et al., 1992).

2.4.2.3 Reproduction of Detail

PVS materials are currently used to produce most detailed impression materials. The international standard for dental elastomeric impression materials states that a Type 3 (light body) impression material should produce a line that is 0.020 mm wide. Light, medium, and heavy body PVS materials achieve this standard. Very low-viscosity materials can reproduce lines that are 1 μm –2 μm wide (Manappallil, 2010; Derrien and Le Menn, 1995).

2.4.2.4 Dimensional Stability

The accuracy of an impression material depends on its dimensional stability. Addition silicones, also known as PVS materials, are the most accurate and stable impression materials (Gladwin and Bagby, 2009). Dimensionally stable materials are materials that resist shrinkage during storage (Cartmen, 2010).

Compared with other impression materials, addition silicones demonstrate the least dimensional changes after setting because of their low-dimensional variation and high-elastic recovery. The dimensional change of approximately -0.1% within 24 h is low. The elastic recovery of this material at the time of removal from the mouth of approximately 99.8% (permanent deformation of 0.2%) is the highest among all impression materials (Powers and Wataha 2008; Chee et al., 1992).

The stability exhibited by addition silicones and PE materials suggests that these impressions do not have to be immediately poured with a gypsum product. These impressions are often sent to the laboratory to be poured. A previous study has shown that a cast produced between 24 h and 1 week can be as accurate as a cast made within 1 h, assuming that no hydrogen bubble is formed. These materials exhibit the least distortion from the loads imposed on the set material. Thus, pouring the impression and removing the cast several times will not alter the dimensional stability of the impression, although a fairly substantial force is required each time the cast is removed from the impression.

PE impressions are negatively affected by water or fluid absorption and the simultaneous leaching of water-soluble plasticizer. Thus, the stored impression should be stored in a dry and cool environment to maintain its accuracy (Anusavice et al., 2013).

2.4.2.5 Tear energy, elastic recovery, and deformation

Impression materials should have sufficient strength to allow their removal from the gingival sulcus without tearing. Tear energy is the energy required to sustain a tear through a material and is important in thin intra-sulcular or inter-proximal areas. Elasticity is inherent to all elastomeric impression materials because these polymers have highly flexible kinked segments, resulting in their free movement. Under a load, the flexible kinked segments of these polymers uncoil to allow movement. Upon removal of the load the optimal elastomer exhibits complete elastic recovery and returns to its pre-stress configuration. The degree to which this recovery occurs is a measure of the elastic recovery of the material. A polymer becomes permanently deformed when it is elongated beyond the limit for elastic recovery. Permanent deformation is related to the degree of cross-linking of the polymer strands, temperature, and rate of applied stress (Hondrum, 1994).

The optimal impression material should exhibit maximum energy absorption with minimal distortion. However, this material should also tear rather than deform beyond a critical or marginal point. PVS materials deform at slower rates and tear at points of less permanent deformation compared with other elastomeric materials. PVS materials are frequently reported to be the optimal elastic impression materials because they exhibit higher elastic recovery and less permanent deformation than other elastomers. These materials can also absorb more than thrice as much energy until the point of permanent deformation than other elastomers, as well as rebound to only 0.6% permanent deformation if elongated to higher than 100% (strain at tear) (Anusavice et al., 2013; Hondrum, 1994). PVS materials tear before the limit of permanent deformation and have the highest tear strengths. Therefore, these materials are more suitable for clinical applications because they deform within the range of their yield strength (Hondrum, 1994; Craig, 2001).

Low-viscosity impression materials are used in inter-proximal and sub-gingival areas during the impression production. The sub-gingival regions of the impression are often very thin and can tear during impression removal, thus leaving a portion embedded within the gingival sulcus.

Tear strength is the strength of the force required to tear a specified test specimen divided by the thickness of the specimen. No standard method for the evaluation of the tear strength of impression materials has been established. ISO 4823 (Dentistry—Elastomeric impression materials) is not used for such purpose.

A tear strength test determines the resistance of an elastomeric material against fracture when subjected to a tensile force perpendicular to the surface defect. The impression materials according to increasing tear stresses are as follows: silicones (addition and condensation), PEs, and Polysulfides.

Tear strength is affected by consistency and the method of material removal. The tear strength of the material is usually enhanced by increasing material consistency. The elasticity of a material is substantially improved by the addition of a thinning agent to the mixture, but this process slightly reduces the tear strength. A rapid removal of the impression usually increases the tear strength because the resistance of the material against deformation (strain) increases.

No dimensional change for the test specimen is inferred in tear strength. Regardless of the magnitude of its tear strength, an impression material undergoes a specific amount of strain during removal. For the same tooth preparation, a material that can be considerably stretched elastically before fracture will likely remain as more intact than a material that fractures at a lower tensile strain. Thus, using tear strength to distinguish the resistance of an impression material against tearing is not very meaningful (Anusavice et al., 2013).

2.4.2.6 Elasticity

Elasticity is the ability of a material to return to its original shape after deformation. The modulus of elasticity (Young's modulus, *E*) is one of the most important properties of solid materials because it describes the stiffness of a material. Mechanical deformation provides energy to a material. The energy is stored elastically or dissipated plastically. The method by which a material stores this energy is summarized in stress–strain curves. Stress is defined as force per unit area, whereas strain is described as elongation or contraction per unit length.

When a material elastically deforms, the degree of deformation depends on the size of the material, but the strain for a given stress is unchanged. Stress and strain are related through Hooke's Law (Faridmehr et al., 2014) (stress is directly proportional to the strain):

$$\sigma = E \times \varepsilon$$

Where σ is the stress (Mpa), E is the modulus of elasticity (Mpa), and ε is the strain (unitless or %).

The elastic properties of these elastomeric impression materials are enhanced with increasing oral curing time. Thus, the longer the impression can remain in the mouth, the less distortion will occur during impression removal. The impression material should undergo elastic distortion during its removal from the mouth. A sufficiently high elastic limit for the impression material minimizes permanent deformation.

The relative degree of permanent deformation following strain in compression increases in the following order: addition silicones, condensation silicones, PEs, and polysulfide's. The recovery of elastic deformation following strain is slower for polysulfide's than those for the three other compounds. However, even when strain is prolonged, such as when an impression is removed slowly from the prepared teeth, recovery is sufficiently rapid so pouring of the impression should not be delayed.

Despite the possibility of a large dimensional change during the removal of polysulfide impression from the mouth, "bench curing" the materials is not advantageous. If the polymer chains have been stretched beyond their elastic limit, no amount of waiting will facilitate the recovery to the original shape. Although the distortion is permanent, the chains may relax but may have no "memory;" hence, the relaxed state will probably differ from the undistorted shape regardless of the curing duration of the impression (Anusavice et al., 2013).

PVS impression materials exhibit poor elasticity and are more rigid than polysulfide's. Thus, an additional spacing of approximately 3 mm should be provided in the impression tray. The stone cast should also be carefully removed from the impression to avoid any breakage (Powers and Wataha, 2008).

Excluding the very high-viscosity putty class of elastomers, the rigidities of impression materials increase in the following order: polysulfide, condensation silicone, addition silicone, and PE. The original PE material is extremely