THE EFFECT OF STORAGE TIME ON DIMENSIONAL ACCURACY OF ELASTOMERIC IMPRESSION MATERIALS

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KEYWORDS

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Dimensional stability

Dimensional accuracy

Storage time

ABSTRACT

The effect of storage time on dimensional accuracy of elastomeric impression materials.

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Several factors play a role in stability of impressions made from elastomeric impression materials. These include; polymerization shrinkage, loss of by-products during condensation, thermal contraction from oral temperature to room temperature, imbibition when exposed to water, disinfectant or high humidity and incomplete recovery from deformation due to viscoelastic behavior. An ideal impression material should be dimensionally stable over time to allow for pour at the convenience of the operator. Several studies evaluated the dimensional accuracy of elastomeric impression materials based on various factors including effects of repeat pour, temperature, humidity, disinfectants, impression techniques, and filler loading amongst others. Most of the previous studies did not use the standardized method described by the ADA specification for elastomeric impression materials.

Title: The effect of storage time on dimensional accuracy of elastomeric impression materials. **Aim and Objectives:** The objective of this study was to investigate indirectly on stone casts the long-term dimensional accuracy of standardized impressions of a stainless steel master die taken with selected elastomeric impression materials when the impressions are stored at the same environmental humidity and temperature and poured at different storage times of 0, 3 , 5 and 7 days respectively. **Materials and methods:** A total of 60 impressions of a standardized stainless steel die similar to that specified by ADA specification number 19 were recorded. The materials tested included Impregum, Permadyne-Impregum combination, and President. 20 impressions were taken per material combination. The baseline measurements were made on the casts poured from the 0 days storage experimental group impressions using a traveling microscope accurate to 0.01mm. Subsequent readings were taken from models after 3, 5 and 7 days of delayed pour respectively. **Results:** The results were analyzed using the Wilcoxon Signed Rank Sum test, Kruskal Wallis test and Chi square test.

DECLARATION

I hereby declare that "The effect of storage time on dimensional stability and accuracy of elastomeric impression materials" is my own work, that it has not been submitted before for any degree or examination in this or any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Dr. Osio A. Mary

October, 2008

Signed: .....

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DEDICATION

To my loving husband and best friend Jared Opiata for the great sacrifice he made to take care of our lovely daughters Debby and Diana while I was away studying, for his never ending support and encouragement throughout the course and for believing in me.

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CHAPTER 1

1 INTRODUCTION

There are a host of excellent impression materials available commercially for making impressions in restorative dentistry. However, proper material selection and observation of manipulative variables is mandatory for optimal results. Several factors play a role in stability of impressions, these include; polymerization shrinkage, loss of by-products (water and alcohol) during condensation, thermal contraction from oral temperatures to room temperature, imbibition when exposed to water, disinfectant or high humidity and incomplete recovery of deformation because of viscoelastic behavior (Brown, 1981; Williams *et al,* 1984; Chong *et al*, 1990; Johnson *et al*, 1998; Cynthia *et al*, 2003; Anusavice, 2003).

The above mentioned factors contribute greatly to the accuracy and dimensional stability of an impression and the cast made from the impression. An ideal impression material should be dimensionally stable over time to allow for pour at the convenience of the operator and for the impression to be sent to long distance laboratories.

Several studies have evaluated the dimensional accuracy of some of the elastomeric impression materials based on various factors including effects of repeat pour, temperature, humidity, disinfectants, impression techniques, and filler loading amongst others (Gilmour *et al*, 1959; Stackhouse, 1970; Johnson and Craig, 1985; Tjan *et al*, 1992; Purk *et al*, 1998; Taylor *et al*, 2002; Chen *et al*, 2004; Pank *et al*, 2008) with some studies having considered the dimensional accuracy of the elastomeric impression materials with storage time (Sawyer *et al*, 1974; Eames *et al*, 1979; Lacy *et al*, 1981; Williams *et al*, 1984; Purk *et al*, 1998; Chen *et al*, 2004; Pank *et al*, 2008). However, due to the various conditions impressions are subjected to during freight including long storage times and extreme fluctuation in temperatures, there is a need to assess the stability of materials under these harsh conditions.

1.1 Definition of terms

For the purpose of this study the following terms will be defined as follows based on the Glossary of Prosthodontics (1999):

- **Elastomers:** Elastomers refer to a group of rubbery polymers that are chemically or physically cross-linked. They can be easily stretched and rapidly recovered to their original dimensions when the applied stress is released.
- **Dental cast:** According to the Glossary of prosthodontic terms a dental cast is a positive life size reproduction of a part of the oral cavity formed when a material is poured into a matrix or impression of the desired form.
- **Dimensional stability:** This is the ability of a material to retain its size and form over time. The dimensional stability of impression materials is affected by chemical reactions and their by-products.
- **Dies:** According to the Glossary of prosthodontic terms a dental die is a positive reproduction of the form of a prepared tooth.
- **Viscosity:** is defined as the material property that controls the flow characteristics of a material.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Introduction

The techniques for fabricating a definitive impression are critical in producing biologically, mechanically, functionally, and esthetically acceptable restorations in restorative dentistry. The details reproduced in the impressions greatly affect the quality of the final casts and dies produced subsequently (Anusavice, 2003; Donavan and Chee, 2004).

Essentially, fabricated restorations should have an ideal marginal fit, internal fit, interproximal contacts, and occlusal contacts. In addition, the impression material should reproduce the hard and soft tissue around the prepared and adjacent teeth (Jung *et al*, 2007). The elastomeric impression materials have two main advantages, in good tear resistance and dimensional stability over the earlier impression materials such as the hydrocolloids (Wassell *et al*, 2002; Chen *et al*, 2004).

Purk *et al* (1998) documented that mail or parcel services are typically used to transport impressions to dental laboratories. They found that the transportation process can expose dental impressions to extreme temperatures and storage times during freight. This can affect the accuracy of the impression. They also reported that in Kinshasa the temperature in the delivery vehicle can go up to a high of 66ºC when the outdoor temperature is 32º C. In the United States during winter the outdoor temperatures have been reported to be as low as 0ºC for weeks while the indoors temperatures can go up to 21ºC. In addition, a conversation reported in Purk *et al* (1998), between one of the authors and a U.S Postal Service employee in May 1991 indicated that it is not unusual for the parcels to stay in the delivery vehicles for more than eight hours during the delivery process (Purk *et al* 1998).

It is postulated that the polyether and the addition-cured silicone elastomeric impressions do not have to be poured immediately and can be sent to long distance laboratories without much dimensional change (Marco *et al* 1998; Chen *et al*, 2004; Donavan and Chee, 2004). In addition, it is also postulated that these impressions can be poured

repeatedly producing unchanged resultant dies (Lacy *et al*, 1981; Marco *et al*, 1998; Wassell *et al*, 2002; Donavan and Chee, 2004).

The objective of this study was to determine the most accurate and dimensionally stable commonly used impression material, when the pouring of the cast was delayed. The method involved taking measurements of a stainless steel die similar to that described in ADA specification 19 using a traveling microscope.

2.2 Impression materials

2.2.1 Ideal properties

The ideal properties of an impression material include; accuracy, elastic recovery, dimensional stability, flow, flexibility, workability, hydrophilicity, long shelf-life, patient comfort, and economics. Impression materials vary considerably in relation to these ideal properties, and these differences may provide a basis for the selection of a specific material under different clinical situations (Anusavice, 2003; Donavan and Chee, 2004).

In addition, an ideal impression material should accurately record the oral structures, be removed easily from the oral cavity without distortion, remain dimensionally stable on the laboratory bench after pouring a gypsum product into the impression and have minimal distortion on removal from the impression surface (Wassell and Ibbetson, 1991; Donavan and Chee, 2004).

2.2.2 Minimum requirements

Dental biomaterials have over the years been tested and certified according to requirements of standards or specifications as they are referred to in American terminology. These standards are determined by national or international standards organizations. The first standard for testing of a dental material was established by the American Dental Association (ADA) working under the auspices of the American National Standards Institute (ANSI) and it was developed for dental amalgam (Mjor, 2007).

The ADA approved or certified materials were considered a sign of quality and were an important factor in the marketing of the materials. However, since the early 1960s, the International Organization for Standardization (ISO) took over the development of

standards for testing dental materials (Mjor, 2007). These standards are based on the physical properties of the materials. A number of tests are described in standards for dental materials. Standardization and certification of dental materials remain important for quality control in the manufacturing of dental materials (Mjor, 2007).

However, it is questionable as to whether the clinical significance of these exercises guides clinicians when selecting dental materials in the management of patients. A study by Sarrett (2005) confirmed that physical parameters in standards for dental materials do not reflect the clinical performance of the material hence, clinical studies, "controlled clinical trials" or a "practice-based approach", seem to be the only way to accurately test dental restorative materials (Mjor, 2007).

The choice of the materials, the quality of the impression and quality of the cast are also influenced by the environmental conditions and the characteristics of the tissues at the time of impression taking. The ideal requirements for impression materials as summarized by Anusavice (2003) include;

- Material should be fluid enough to adapt to the soft and hard oral tissues.
- Material should be viscous enough to be contained in the tray that is seated in the mouth.
- Inside the mouth the material should transform into a rubbery or rigid solid in a reasonable period of time, ideally total setting time should be less than seven minutes.
- The set impression should not distort or tear on removal from the mouth.
- Impression should remain dimensionally stable until the cast is poured.
- Impression should remain dimensionally stable after being poured so as to get a second and third cast from the same impression.
- Material should be biocompatible.
- The processing equipment and the processing of the material should be cost effective.

2.2.3 Classification of impression materials

Impression materials are classified according to their elastic properties once set and are broadly divided into non-elastic and elastic materials (Figure 2.1). Non-elastic impression materials are generally not used for obtaining impressions of crown preparations because of their inability to accurately record undercuts (Wassell *et al*, 2002). The elastic impression materials are further divided into two groups: the hydrocolloids and the synthetic elastomers (Wassell *et al*, 2002). The hydrocolloids are further divided into the reversible hydrocolloids (Agar-agar) and the irreversible hydrocolloids (Alginate) while the synthetic elastomers are further divided into polysulphides, polyethers and silicones.

Hydrocolloids

Sears first introduced agar-agar impression material into dentistry for recording crown impressions as the first elastic impression material in 1937. However, its use in clinical practice is obsolete because of the need for expensive conditioning baths and water cooled trays. Alginate, unlike agar, does not require any special equipment (Anusavice, 2003).

Alginate and agar produce impressions with reasonable surface detail. They are hydrophilic and are not displaced from wet surfaces as easily as the synthetic elastomers. However; these materials have two major disadvantages when it comes to recording crown preparations. Firstly, they have poor dimensional stability because of their susceptibility to loss or imbibition of water on standing in dry or wet environments respectively. Secondly, they exhibit a low tear resistance which is a major problem when attempting to record the gingival sulcus (Brown, 1981; Wassell *et al*, 2002; Anusavice, 2003).

Synthetic elastomers

The synthetic elastomers were introduced in dentistry in the early 70s and have simplified restorative procedures when compared to the non-elastic materials as regards impression procedures. Surface detail reproduction has also improved greatly with the evolution from reversible hydrocolloids to polysulphides, polyethers and silicones (Johnson *et al,* 2003). The silicone impression materials are further divided into the condensation and

addition-curing silicones depending on their curing mechanism (Anusavice, 2003; Craig and Robert, 1997). The classification of impression materials is illustrated in Figure 2.1.

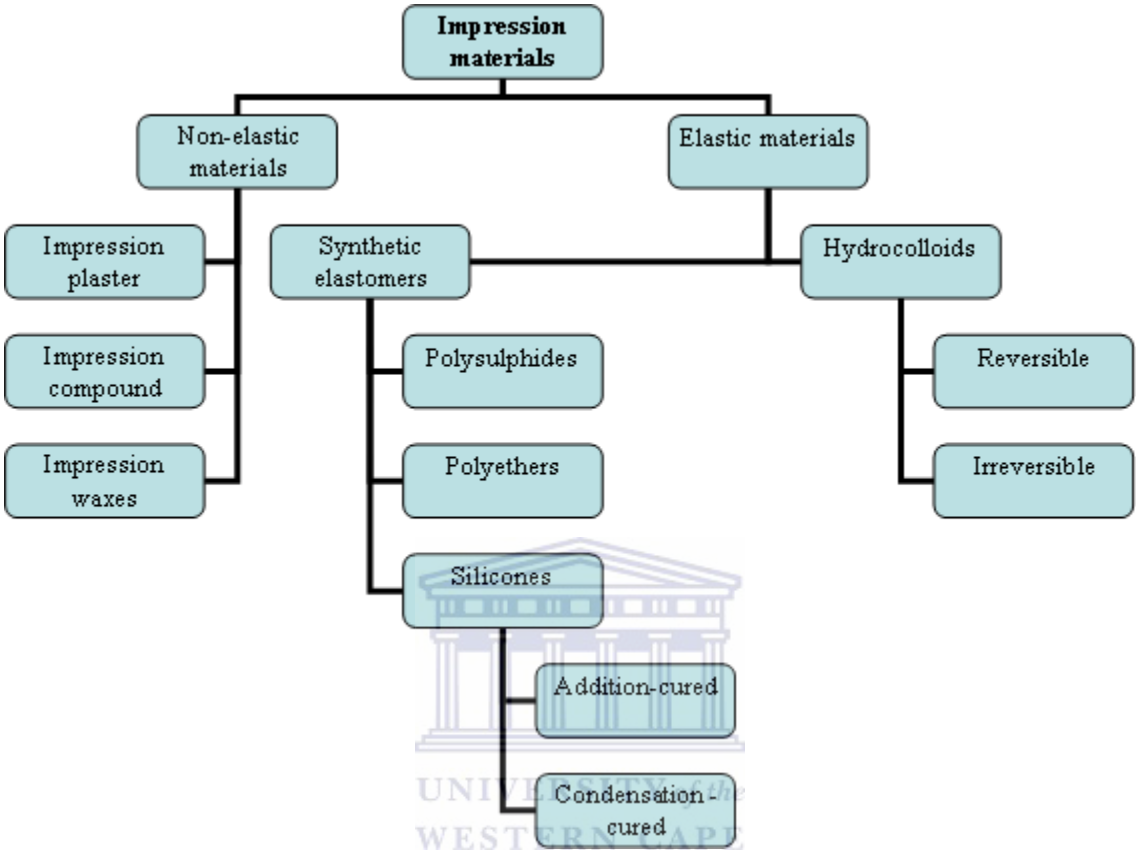

Figure 2.1: Classification of impression materials (Wassell *et al,* 2002)

Table 2.1 summarizes the available impression materials, their advantages, disadvantages, recommended uses and precautions.

Materials	Advantages	Disadvantages	Recommended use	Precautions
Irreversible Hydrocolloid	Rapid set. Straightforward technique. Low cost.	Poor accuracy and surface detail.	Diagnostic casts. Not for working casts.	Pour immediately.
Reversible hydrocolloid	Hydrophilic Long working time Low cost No special tray required	Low tear resistance Low stability Equipment needed	Multiple preparations Problem with moisture	Pour immediately Use stone only
Polysulphide polymer	High tear strength Easier to pour than other elastomers	Messy Unpleasant order Long setting time Stability not so fair	Most impressions	Pour within 1 hour. Allow to set for 10 minutes
Addition-cured silicone	Dimensionally stable Pleasant to use Short setting time Auto-mix available	Hydrophobic Poor wetting Some materials release Hydrogen gas Hydrophilic formulations imbibe water.	Most impressions	Delayed pour of some materials Care to avoid bubbles when pouring
Condensation-cured silicone	Pleasant to use short setting time	Hydrophobic Poor wetting Low stability	Most impressions	Pour immediately Care not to inco-operate bubbles
Polyether	Dimensionally stable Accuracy Short setting time Auto-mix available	Set material stiff Imbibition Short working time	Most impressions	Care not to break teeth when separating from cast.

Table 2.1: Summary of the available impression materials (from Rosenstiel, 2006)

2.3 Elastomeric impression materials

2.3.1 Introduction

The synthetic elastomers were introduced in dentistry in the early 70s and have simplified restorative procedures when compared to the non-elastic materials as regards impression procedures. Surface detail reproduction has also improved greatly with the evolution from reversible hydrocolloids to polysulphides, polyethers and silicones (Johnson *et al*, 2003).

These materials can be stretched and bent to a fairly large degree without suffering any permanent deformation. Polyvinyl impression materials have the best elastic recovery at over 99% with a specific test undercut (Donavan and Chee, 2004). They are recommended for use where a high degree of accuracy is needed, especially in crown and bridge work (Craig and Robert, 1997; Anusavice, 2003; Rosenstiel *et al* 2006). In addition they are commonly used as impressions for partial dentures, overdentures, and implant retained dentures.

2.3.2 Polysulphides

Polysulphides have the longest history of use in dentistry of all the elastomers. They were first developed as industrial sealants for filling of the gaps between sectional concrete structures (Craig and Robert, 1997). They are available in a range of viscosities namely; light bodied (low viscosity), medium or regular bodied and heavy bodied (high viscosity).

However, their disadvantages include a long setting time in excess of 10 minutes, they are messy to handle and they have an unpleasant odor. Polysulphides have also been shown to undergo polymerization shrinkage with subsequent production of shorter and wider dies than the respective tooth preparations with the distortion worsening with a delay in pour of the impression (Wassell *et al*, 2002).

Shrinkage occurs firstly as a result of a continued setting reaction after the apparent setting time, and secondly through the evaporation of water produced as a by-product of the setting reaction. A special tray, providing a 4 mm uniform space, is needed to reduce distortion from the shrinkage of a large bulk of material. The recommended maximum storage time of the set impression is 48 hours (Craig and Robert, 1997; Anusavice, 2003; Donavan and Chee, 2004).

The advantages of polysulphide impression materials are their long working time; a property useful when an impression of multiple preparations is required. They possess excellent tear resistance and undergo a considerable tensile strain before tearing. However, their elastic properties are not ideal and some of this strain may not be recovered leading to distorted impressions and inaccurate dies (Anusavice, 2003; Craig and Robert, 1997). To overcome this limitation, the impression should be removed with a single, swift pull as the strain imparted on the material is a function of the time over which the load is applied (Wassell *et al*, 2002; Anusavice, 2003).

2.3.3. Polyethers

One of the most popular polyether impression material, Impregum (Espe GmbH, Germany), was the first elastomer to be developed specifically for use in dentistry and introduced in the late 1960s. Initially it was available only in a single 'regular' viscosity but recently a light bodied system has been introduced (Permadyne, Espe GMbH, Germany) (Wassell *et al,* 2002).

Polyether impression materials tend to have a fast setting time of less than five minutes and, for this reason, have been popular for the recording of single preparations in general practice. Unlike the polysulphides, they undergo an addition-cured polymerization reaction on setting which has no reaction by-product resulting in a material with very good dimensional stability (Anusavice, 2003; Brown, 1981). However, the resultant impression may swell and distort because of the imbibition of water on storage in conditions of high humidity and it is advocated that the impressions be stored dry (Craig and Robert, 1997; Anusavice, 2003).

Their hydrophilic nature makes them more forgiving of inadequate moisture control than the hydrophobic polysulphide and silicone rubbers. The polyethers have adequate tear resistance and very good elastic properties. However, considerable amount of force may be required to remove the impression from both the mouth and the stone cast due to their high elastic modulus and consequently are relatively rigid when set. Their use in cases where severe undercuts prevail is not advocated (Craig and Robert, 1997; Anusavice, 2003).

2.3.4 Silicones

Silicone impression materials are classified according to their method of polymerization on setting, they include:

- Condensation curing (or Type I) silicones
- Addition curing (or Type II) silicones.

They are available in a similar range of viscosities; light, medium and heavy. However, a fourth very high viscosity or 'putty' material was formulated with a high filler loading devised to reduce the effects of polymerization shrinkage. The putty is commonly combined with a low viscosity silicone when recording impressions, a procedure known as the 'putty-wash technique' (Anusavice, 2003; Craig and Robert, 1997; Wassell *et al*, 2002.

As with the polysulphides, the setting reaction of the condensation-cured silicones produces a volatile by-product, but with type I silicones it is ethyl alcohol, not water. Loss of the by-product leads to a measurable weight loss of the impression that is accompanied by shrinkage of the impression material on storage (Brown, 1981; Anusavice, 2003).

The dimensional changes of the condensation-cured silicones are greater than those of the polysulphides, but the changes in both types of material are small in comparison to the changes which occur with the alginates. Nevertheless, to produce the most accurate models, regular and heavy body impressions should be cast within 6 hours of being recorded (Craig and Robert, 1997). This may be a problem if the laboratory is not close to the practice or if the impression has to be packaged for freight to overseas laboratories as it happens in most African countries.

Addition-cured silicone rubbers are considered the most dimensionally stable impression materials (Johnson and Craig, 1985; Anusavice, 2003; Donavan and Chee, 2004). Like polyethers, they set by an addition-cured polymerization reaction. No by-product is produced during cross-linkage resulting in an extremely stable impression which has been shown to remain unchanged over a long period of time, hence allowing impressions

to be poured at leisure some days after they were recorded (Anusavice, 2003; Craig and Robert, 1997).

They are hydrophobic and moisture control is mandatory to avoid voids in the set impression. These materials have the best elastic properties of any impression material with an instantaneous recovery of strain. Like the other elastomers, they have adequate tear resistance; are non-toxic and absolutely neutral in both colour and taste (Anusavice, 2003; Craig and Robert, 1997; Wassell *et al*, 2002).

Recent research has centered on the production of hydrophilic silicone rubbers and some addition-cured products have been introduced (Take 1 Kerr US, Missouri USA). A study by Pratten and Craig (1989) showed one of these 'hydrophilic' addition silicone materials to have wettability similar to that of the polyethers. In addition, it is documented that treatment of addition-cured silicone impression materials with topical agents, including surfactants, results in a decrease in the number of voids found in the final impression and the dies poured from them (Boening *et al*, 1998).

2.3.5 Composition and Chemistry

Polysulphides

The main component in this group of materials is a multifunctional Mercaptan (-SH) or Polysulphide polymer. The polymer contains 1 mole % of pendant –SH groups. An oxidizing agent like lead dioxide is used to initiate the polymerization reaction through chain lengthening between terminal –SH groups and cross linking between pendant -SH groups. Lead dioxide gives polysulfide its characteristic brown color (Brown, 1981; Anusavice, 2003.).

The reaction starts at mixing and is at its maximum after spatulation is complete at which stage the resilient network is formed during the final set, when a material of adequate elasticity and strength is formed that can be removed past undercuts. Moisture and temperature has a significant effect on the course of reaction, hot and humid conditions accelerate the setting of the polysulphide impression material (Brown, 1981; Anusavice, 2003). The reaction yields water as a by-product. The loss of the water molecules from the set material has a significant effect on dimensional stability of the impression (Brown, 1981; Anusavice, 2003).

The base paste contains a polysulphide polymer, suitable filler (e.g. titanium dioxide) that provides strength, a plasticizer (dibutylphthalate) to confer appropriate viscosity to the paste and a small quantity of sulfur, approximately 0.5% to accelerate the reaction (Brown, 1981; Anusavice 2003). Each paste is supplied in a dispensing tube with an appropriately sized bore diameter at the tip so that equal lengths of each paste are extruded out of each tube to provide the correct ratio of polymer to cross linking agent for an optimal reaction.

Polyethers

This group of materials was introduced in Germany in the 1960's; they are polyether based polymers cured by reaction between ranitidine rings at the end of branched polyether molecules (Brown, 1981; Anusavice, 2003). The main chain is a co-polymer of ethylene oxide and tetrahydrofuran. Aromatic sulfonate ester acts as an initiator to bring about cross linking and setting (Anusavice, 2003).. Polyether elastomers are supplied as two paste systems with the base paste containing the polyether polymer, colloidal silica as filler and plasticizer like glycolether or phthalate. The accelerator paste contains an alkyl- aromatic sulfonate in addition to the filler and plasticizer (Brown, 1981; Anusavice, 2003).

Silicones

Condensation silicones

The basic component of the condensation-cured silicones is alpha omega hydroxyl-terminated polydimethyl siloxane. The curing reaction is by a reaction of tri- and tetra-functional alkyl silicates, commonly tetraethyl orthosilicate in the presence of stannous octoate (Anusavice, 2003).

An average polymer chain consists of 1000 units, the elastomer formation occurs through cross linking between terminal groups of the silicone polymer and alkyl silicate to form a three dimensional network (Anusavice, 2003). Ethyl alcohol is a by-product of the condensation-curing reaction, its evaporation accounts for much of the contraction that takes place in a set condensation-cured silicone elastomer impression (Brown, 1981; Anusavice, 2003).

A high viscosity material commonly referred to as putty was developed to overcome the large polymerization shrinkage of the condensation-cured silicone impression materials. The putties are highly filled with a reduced polymer hence the decreased polymerization shrinkage. The putty is used as a tray material in conjunction with a low viscosity silicone paste (Brown, 1981; Anusavice, 2003)).

Addition-cured silicones

Otherwise known as polyvinylsiloxane or vinylpolysiloxane impression materials; they are terminated with vinyl groups and cross-linked with hydride groups activated by platinum salt catalysts. No reaction by-products develop as long as the correct proportion of vinyl silicone and hydride silicone are maintained and if there are no impurities (Anusavice, 2003).

However a secondary reaction between moisture and residual hydrides of base polymer can lead to the formation of hydrogen gas that may result in pinpoint voids in the gypsum product that is poured immediately after the impression is removed from the mouth. Noble metals like palladium and platinum are added by the manufacturers' to the addition-cured silicones to act as scavengers for the released hydrogen gas; alternatively impressions are stored for an hour or more before being poured with no clinically detectable dimensional change (Anusavice, 2003; Donavan and Chee, 2004).

The base paste contains polymethyl hydrogen siloxane as well as other siloxanes. The catalyst paste contains divinyl polydimethyl siloxane and other prepolymers. If the catalyst contains platinum salt activator then the paste labeled base must contain the hybrid silicone. Both pastes contain fillers; a retarder may also be present in the paste containing the platinum catalyst (Anusavice, 2003).

Silicone impression materials have an inherent hydrophobic nature that can be a disadvantage when the impression is poured. However, a non ionic surfactant is added to the paste to render the surface of the impression hydrophilic, the surfactant migrates towards the surface of the impression material and has its hydrophilic segment oriented towards the surface allowing the impression material to be readily wetted and enhancing the ability of the gypsum product to capture maximum details when poured into the impression (Pratten and Craig, 1989; Anusavice, 2003).

The surfactant makes it easier to pour the impression with gypsum forming slurry because the wet stone has a greater affinity for the hydrophilic surface. However, Boening *et al* (1998) in their study to determine the significance of surface activation of silicone impression materials found that not all materials declared to have surfaces activated by the manufacturers showed hydrophilic properties. From their study, no correlation was found between sulcus reproduction ability and surface activation.

2.3.6 Dimensional accuracy

Dimensional accuracy of an impression material is paramount to the overall success of an impression and the cast made from the impression. The five major sources of dimensional changes are; polymerization shrinkage, loss of by-products (water and alcohol) during condensation, thermal contraction from oral temperatures to room temperature, imbibition when exposed to water, disinfectant or high humidity and incomplete recovery of deformation because of viscoelastic behavior (Brown, 1981; Williams *et al,* 1984; Chong *et al*, 1990; Johnson *et al*, 1998; Cynthia *et al*, 2003; Anusavice, 2003). In addition, handling characteristics such as storage conditions, delayed or repeated pour, and distortion of the impression on retrieval from the stone casts influences the accuracy of the subsequent casts and when multiple casts are poured in the same impression (Chen *et al*, 2004; Johnson and Craig, 1985).

Ideally, the amount of permanent deformation exhibited by an elastomeric impression material should be clinically negligible provided that; the material had adequately gelled, negligible pressure is applied to the tray during polymerization, the impression is removed rapidly along the path of tray insertion and the undercuts present in the cavity preparation are minimal (Wassell and Ibbetson, 1991).

The mean values for linear contraction for a number of non-aqueous elastomeric impression materials shows a greater change in magnitude for polysulphide and condensation-cured silicones than for polyether and addition-cured silicone elastomers. This is due to the fact that the polysulphides and the condensation-cured silicones lose polymerization by-products, water and alcohol respectively whereas the others have no by-products (Anusavice, 2003; Craig and Robert, 1997).

The literature states that the clinical implications of an enlarged or small die are essential in the precise fit of the final prosthesis for an acceptable treatment outcome. A definition of intimate contact used a tolerance of 0.05 mm or less as a measure of good fit (Stern *et al*, 1985). This was based on the limit of clinical detection of 0.05 mm marginal fit by visual examination and explorers applied to gold inlay castings (Christensen, 1966). For metal ceramic crowns marginal discrepancies in the order of less than 0.120 mm might be considered clinically acceptable.

In a recent systematic review on current ceramic materials *in vivo* mean marginal gaps were reported between 0.065mm and 0.195 mm (Conrad *et al,* 2007). However, there is significant variability as to what is considered clinically acceptable on even a relatively simple consideration such as a single crown margin, with prosthodontists accepting a marginal discrepancy as large as 0.455 mm and rejecting margins as small as 0.117 mm (Bronson *et al*, 2005)

As pertains to removable prostheses a discrepancy of 0.18mm on a cast metal framework was reported to be sufficiently large to admit a dental probe and despite the lack of evidence-based research, an acceptable degree of tolerance to intimate fit for a removable prosthesis is generally recognized to be 0.100 mm. An appliance having a larger discrepancy of fit is thought to cause potential damage to both teeth and soft tissues and possible failure (Likeman *et al,* 1996).

The accuracy of impression materials can be evaluated in two ways. According to American Dental Association specification number 19, elastomeric impression materials used to fabricate precision castings must be able to reproduce fine detail of 25 mm of the cross line or less. Polyvinylsiloxane impression materials are considered the best in this regard (Chen *et al*, 2004, Marco *et al* 1998; Donavan and Chee, 2004).

Other methods of measurement involve measuring tooth-to-tooth distances within the same quadrant and across the arch. However, greater differences resulting from the use of different die stones or the manipulation of the gypsum are found than exist between different types of impression materials (Ohsawa and Jorgensen 1983; Donavan and Chee, 2004).

2.3.7 Previous studies on dimensional accuracy

Numerous investigations have been done regarding the effect of delayed and repeated pours on the accuracy of elastomeric impression materials. Earlier studies concluded that impressions must be poured immediately in order to come up with accurate casts. Gilmore *et al* (1959) in an earlier study on the accuracy of rubber impression materials concluded that immediate pour of the silicone impression materials was mandatory in order to eliminate distortions. They also concluded that the use of a double mix technique regardless of the mixing technique of the impression material gave more accurate results than the single mix technique. In addition, they found that a uniformly thin (2.0mm or less) layer of silicone material produced more accurate results than thicker or unevenly distributed masses of materials.

A subsequent study by Stackhouse (1970) on the accuracy of stone dies made from elastomeric impression materials supported the findings of Gilmore *et al* (1959). He found that bench setting for all materials tested caused the stone dies poured successively from the same impression to become increasingly shorter in length and wider in diameter. The hourly dimensional change of the elastomers was greater than that specified by the ADA. specification No. 19 which is not more than 0.4% in 24 hours for type I elastomers and 0.6% for type II elastomers.

With the advent of newer impression materials, the above findings became outdated as newer materials could be poured at the operator's convenience as documented by several authors on delayed and repeat pour of impressions with acceptable dimensional stability values. Sawyer *et al* (1974) in their study concluded that polyether was the only material where a second accurate cast in the same impression or a delayed pour after a week, produced essentially the same accuracy, compared to that of the cast poured immediately. However, the delayed excessive shrinkage of silicones at that time did affect the second and delayed pours.

The finding of Sawyer *et al* (1974) on silicone impression materials was however disputed by the findings of several other authors (Eames *et al* 1979; Lacy *et al*, 1981; Marcinak and Draughn, 1982; William *et al*, 1984; Johnson and Craig, 1985; Tjan *et al*, 1986; Tjan *et al*, 1992; Pank *et al*, 2008) who evaluated the accuracy and dimensional

stability of elastomeric impression materials and concluded that the new addition-cured silicones exhibited the least change dimensionally. They were found to be statistically equivalent to the polyethers. They recommended that in situations, which preclude the immediate pouring of impressions only the stable materials should be selected. Marcinak and Draughn (1982) also concluded that addition-cured silicone impression materials remained remarkably accurate even after one week, with the greatest change at any time being -0.3%. Some materials in their study actually underwent contraction while others exhibited minimal expansion.

In addition, some authors combined more than one variable in the dimensional stability studies and came up with additional recommendations. Lacy *et al* (1981) in their study on time dependant accuracy of elastomeric impression materials concluded that the polyvinylsiloxane materials were the most stable of elastomers currently available and that accuracy and consistency are best maintained by the use of custom trays and adhesives to retain the material. Furthermore, they found that the putty-wash impression technique may reveal some loss of accuracy of dies produced by retrieval from multiple pours after 2-4 days. There was no marked difference between the single and double mix impression techniques. Chen *et al*, (2004) in their study evaluated the effects of different storage times and filler particle content on dimensional accuracy for different impression materials. They reported that addition-cured silicones had the greatest stability with storage time. They also concluded that the higher the filler loading the more stable the impression material.

A study by Purk *et al*, (1998) investigated amongst other variables the effect of extreme temperature changes on elastomeric impression materials. The authors compared the effects of different time and temperature storage conditions, including temperature extremes of 66°C and 10°C, on the accuracy of addition-cured silicone and polyether impressions. The greatest distortion occurred as a result of the 66°C temperature extreme. They recommended that to minimize the effect of extremes in time and temperature conditions, it may be advantageous to package the impression for mailing in insulated containers during the summer and winter months to avoid exposing the impression to extremes in temperature (Purk *et al*, 1998). Pant *et al*, (2008) varied the storage temperatures of the current polyvinylsiloxane impressions and found that none of the

materials showed a change in dimension greater than 2% and the tested materials showed good dimensional stability over the time period of the study.

The Council on dental materials, Instruments and Equipment (1990) in a status report on the polyvinylsiloxane impression materials recommended that the advantages of using the polyvinylsiloxane included the ability of the impression to be poured after one hour, one day or even in the case of some products after one week without significant loss of accuracy and there was also the possibility of repouring the impression a second time and producing a cast as accurate as the original (Council on Dental Materials, Instruments, and Equipment. 1990).

Detailed literature reviews by Anusavice (2003) and Donavan and Chee (2004) on non-aqueous elastomeric impression materials reported that, addition-cured silicones are the most dimensionally stable of all the existing materials. This stability means that the impression does not have to be poured in stone immediately and can often be sent to the laboratory to be poured. They also reported that the combination of excellent dimensional stability and superior elasticity of addition-cured silicones means that multiple casts made from the same impression give the same degree of accuracy.

ADA specification number 19 recommends a maximum negative change in dimension to be 0.5% after a minimum of 24 hours. The unrestrained dimensional change after setting has been reported by several authors (Eames *et al* 1979; Ohsawa and Jorgensen 1983; Purk *et al*, 1998; Pant *et al*, 2008). The values show some variation from product to product of the same type as captured in Table 2.2 with the addition-cured silicones being the best.

Impression material	**Dimensional stability after 24 hours in 50% humidity (%)**	**Dimensional stability after 7 days in 50% humidity (%)**
Addition-cured silicones	-0.5 to -0.1	-0.1 to -0.2 and 0.4
Polyethers	0.1 to -0.1	-0.1 to 0.2 (Permadyne is -0.25)
Polysulphides	-0.1 to -0.2	-1.3 to -0.8
Condensation silicones	-0.4 to -0.5	-0.8 to -1.3

Table 2.2 Summary of ADA specification number 19 recommends a maximum negative change in dimension to be 0.5% after a minimum of 24 hours and experimental values as above after 7 days.

Table 2.2 summarizes studies over 45 years of use of elastomeric impression materials. The evolution of the composition of these may be responsible for the differences in performance of the materials within the groups.

Authors	**Year of study**	**Test condition**	**Materials**	**Best results on accuracy.**
Gilmore *et al*	1959	Delayed pour & Impression technique	Elastomers	Immediate pour Double mix technique
Stackhouse,	1970	Repeated pour	Elastomers	First pour is best.
Sawyer *et al*,	1974	Delayed pour	Polyether(PE) & PVS	Polyether.
Eames *et al*,	1979	Delayed pour	Addition-cured silicones & PE	Both materials accurate.
Lacy *et al*,	1981	Delayed pour Technique Tray adhesive	Elastomers	PVS best. No effect of technique.
Williams *et al*	1984	Delayed pour	Elastomers	Addition-cured silicones
Johnson and Craig	1985	Delayed pour& Repeat pour	Elastomers	Addition-cured silicones
Tjan *et al*	1986	Delayed pour of up to 1 week	Elastomers	Addition-cured silicone & PE
Marcinak and Draughn	1992	Delayed pour up to1week	Addition-cured silicones	No significant change (-0.3%)
Tjan *et al*,	1992	Repeated pour	PVS	Stable
Purk *et al*,	1998	Extreme Temperature & storage time	Elastomers	All unstable under extreme temperature
Chen *et al*,	2004	Storage time & Filler loading	Elastomers	PVS & Highly filled Materials.
Pank *et al*,	2008	Delayed pour Different storage temperatures	Polyvinylsiloxane	Dimensional change less than 2%.

Table 2.3 Summary of some of the previous studies done on dimensional accuracy of elastomeric impression materials under different test conditions including storage time

2.3.8 Surface detail reproduction

As pertains to surface detail reproduction, several impression material investigations have concentrated on replication of the finish line of a wet tooth preparation or gingival sulcus reproduction in the presence of crevicular moisture (Takahashi and Finger, 1991; Boening *et al*, 1998; Pant *et al*, 2008). These studies have reported conflicting results regarding the ability of addition-cured silicones to obtain impressions in the presence of moisture with one investigator (Cynthia *et al*, 2003) reporting that hydrophilic addition-cured silicone impression materials when used on wet or moist conditions did not always produce acceptable impressions.

Other authors found that even though there appeared to be differences in the contact angle formed between different addition-cured silicone impression materials and moist tooth surfaces, the hydrophilic addition-cured silicones always obtained a complete impression (Pratten and Graig, 1989; Boening *et al*, 1998)

In a more recent study, Pant *et al,* (2008) investigated the ability of addition-cured silicone impression materials to reproduce fine detail using scanning electron microscopy. A rugosity standard was duplicated in four materials. Specimens were mounted on aluminium stubs using epoxy resin and were sputter coated with gold. All specimens were viewed using a Scanning Electron Microscope (SEM). Their results at baseline showed that all the materials reproduced the surface details of the rugosity graticule exceptionally well. However, after 24 weeks of storage at room temperature and humidity, some materials demonstrated surface corrugations and puckering. They could not explain the corrugations as the materials showed expansion rather than shrinkage during prolonged storage; they speculated that the materials with higher Shore A hardness values maintained their surface topography better than the materials with lower values (Pant *et al,* 2008).

2.3.9 Handling characteristics

Introduction

The use of elastomeric impression materials to fabricate gypsum models, casts and dies involve five major steps which include; preparing the tray, preparing the material, making

an impression, removing the impression, and preparing stone casts and dies (Craig and Robert, 1997; Anusavice, 2003; Rosenstiel *et al,* 2006).

Distortion of an impression is not only due to the material, several other factors such as the space between the tray and tooth preparation, impression techniques, storage conditions, tray material, excessive seating pressure, too slow removal from the mouth or an impression removed before setting time (Tjan *et al,* 1986). The various factors are discussed below.

Impression techniques

The effect of technique on accuracy has been reported by Tjan *et al*. (1984), de Araujo and Jorgensen (1985), and Johnson and Craig (1985) amongst others. They agreed that for polysulphide the use of a custom tray or a double-mix technique produced more accurate impressions than did a single mix in a stock tray. The putty-wash technique gave the most accurate impression for condensation-cured silicones, while no difference in accuracy was found with addition-cured silicone impressions made with the putty-wash, single mix, or double-mix technique. However, even for the addition-cured silicones the use of a custom tray produced more accurate impressions than did the use of a stock tray. The two impression techniques include;

Monophase technique: In the monophase technique the light bodied impression material is placed in a syringe, and placed over the areas where high definition of detail is required (e.g. over a crown preparation). Some of the material is then squirted over the heavy-bodied impression material which has been loaded into an impression tray. The impression is then taken as normal (Rosenstiel *et al*, 2006).

Dual phase technique: In the dual phase technique an impression is taken with the heavy-bodied material. This is then removed from the mouth and inspected. The light bodied material is then prepared and again placed in a syringe. This is then squirted over the heavy-bodied material and the impression relocated in its original position (Rosenstiel *et al*, 2006).

Putty wash technique: The putty-wash technique is probably the most commonly used in general dental practice. Putties were developed initially to reduce the shrinkage of the

condensation-cured silicones. However, the heavy filler loading is not needed for addition-cured silicones since their polymerization contraction and dimensional stability is thought to be excellent. Presumably, addition-cured silicone putty-wash impressions are preferred principally for their handling characteristics (Marcinak and Draughn, 1982; Wassell *et al*, 2002).

There are essentially three ways of recording a putty-wash impression:

- One stage impression - putty and wash are recorded simultaneously (also called twin mix or laminate technique)
- Two stage unspaced – where the putty impression is recorded first and after setting relined with a thin layer of wash.
- Two stage spaced - as for two stage unspaced except a space is created for the wash. This space may be made using a Polythene spacer over the teeth prior to making the putty impression or by recording the putty impression before tooth preparation then gouging away the putty and providing escape channels for the wash impression.

The major cause of distortion in putty wash impressions is recoil which can result in poorly fitting restorations. Recoil works in the following way; Considerable forces are needed to seat putty impressions, which can result either in outward flexion of the tray wall or the incorporation of residual stresses within the material. On removing the tray from the mouth the tray walls rebound resulting in dies, which are undersized buccolingually (Wassell and Ibbetson, 1991).

In another study Carrotte *et al* (1993) investigated the quality of impressions for anterior crowns received at a commercial dental laboratory, it was found that the use of disposable plastic trays for the putty-wash impression technique was routine leading to distorted dies and ill fitting restorations Rigid metal trays can minimize such distortions and are to be recommended for putty-wash impressions.

The two stage technique has been shown to cause distortions which may occur in two ways; one, where it is used in an unspaced tray hydrostatic pressures can be generated during the seating of the wash impression, which can cause deformation and subsequent putty recoil on removal (Wassell *et al*, 2002). Secondly, the putty impression may not be

reseated properly causing a stepped occlusal surface of the cast and a restoration requiring excessive occlusal adjustment (Wassell *et al*, 2002).

One disadvantage of the putty/wash technique is that critical areas of the tooth preparation, including cervical margins may be recorded in the putty material (Donavan and Chee, 2004). Visible flaws related to impression technique which occur commonly include: finish line not visible, air bubbles in critical places, voids or drags and unset impression material on the surface of the impression and the cast. Invisible impression flaws, resulting in an apparently good fit of the restoration on the die but a poor fit on the tooth, may also occur because of tray and impression recoil as described for the putty-wash technique and detachment of the impression from the tray with permanent deformation (Wassell *et al,* 2002)

Effect of Impression trays

Dental material and Restorative dentistry textbooks have stated that a uniform amount of impression material well supported in a custom tray is essential to producing an accurate impression (Anusavice, 2003; Rosenstiel *et al*, 2006). However, the flexion of the walls of the impression trays has been isolated as a potential source of error especially with the high viscosity materials. The tray has a tendency to flex outwards on seating of the impression material. Residual stress may remain in the wall of the tray causing recoil that deforms the impression (Wassell and Ibbetson, 1991).

A rigid acrylic custom-made tray is required to minimize the effect of polymerization shrinkage, loss of reactor by-products, deformation associated with tray seating and removal (Carrotte *et al*, 1993). Custom trays are recommended to reduce the quantity of the materials used to make the impressions and to reduce or minimize the dimensional changes especially for polysulphide impression materials (Anusavice, 2003).

Thongthammachat *et al* (2002) evaluated the influence on dimensional accuracy of dental casts made with different types of trays and impression materials and poured at different times and repeatedly. Two types of stock trays (plastic stock tray, perforated metal stock tray) and four types of custom trays made with auto polymerizing acrylic resin, thermoplastic resin and four types of light-polymerized acrylic resins were used with two types of impression materials (addition-cured silicone and polyether), to make

impressions of a metal master model. They concluded that accurate casts could be made with either stock trays or custom trays for both impression materials.

Fabrication of a custom tray involves intraoral impressions of the area, stone cast construction, important areas covered with one or two layers of base plate wax as a spacer, alluminium foil or model releasing agent is painted for ease of removal of the tray, chemical or light cured acrylic is then applied over the foil or painted wax to form the tray. After curing the resin custom tray is separated from the cast and wax plus alluminium foil is removed and the impression material is manipulated in the area previously covered by the wax (Anusavice, 2003; Rosenstiel *et al*, 2006).

However, the custom made trays have been shown to undergo dimensional changes as well and their immediate use after fabrication may influence the accuracy of the impressions taken in them. Pagniano *et al* (1982) and Goldfogel *et al* (1985) in their studies showed that dimensional changes in acrylic resins for custom trays varied from -0.08 to -0.4% over twenty four hours, with 90% of the shrinkage occurring at eight to ten hours. They recommended that acrylic custom trays should not be used the day of fabrication unless they are placed in boiling water for five minutes to eliminate the distortion caused by dimensional changes. However, they also concluded that boiling the trays in water did not completely eliminate the dimensional changes and acrylic custom trays that had been placed in boiling water still shrunk by 0.06% in twenty four hours.

Effect of tray adhesive

Adhesion of the material to the tray is essential and tray adhesives must be applied. This prevents separation of the impression material from the tray during removal of the tray from the mouth. Tjan *et al* (1987) in their study compared the effect of treatment of the tray on the accuracy of dies; they concluded that an adhesive agent with a perforated tray is the best especially in a situation where a full arch impression of multiple preparations is needed and the presence of undercuts prevail.

Other studies (Russell and Richard, 1991; Davis *et al*, 1976) concluded that for all impression materials, using an adhesive on a non-perforated tray or perforated acrylic tray produces a greater peel bond strength compared to using an adhesive or perforated tray on its own. Uniform thickness of tray adhesive should be applied on the tray and

allowed to dry prior to the insertion of the impression material. Tray adhesive furnished with various impression materials are not interchangeable (Brown, 1981).

Material selection

Selection of the right viscosity for the impression may include multiple mixes or a dual viscosity technique, monophase technique, and putty wash technique (Donavan and Chee, 2004). During manual manipulation the same length of material is dispensed for a two paste system onto a mixing pad or a glass slab. The catalyst paste is first collected onto a spatula and spread over the base paste by spreading over the mixture to get a homogenous color of the mixture. The two putty systems for condensation-cured silicones and addition-cured silicones are dispensed by volume using equal scoops of putty. Material is then kneaded using clean fingers to get a uniform color (Anusavice, 2003; Rosenstiel *et al*, 2006).

Automatic dispensing and mixing devices are available and are interchangeable. They vary in diameter with those for light consistency material being widest and *vise versa* (Jung *et al* 2007). The opening of the tubes dispensing the material should remain unclogged at all times and some amount of material should be dispensed before placing the mixing tip. A dynamic mechanical mixer can be used instead of the double barrel cartridge. Advantages of these devices include the following; greater uniformity in proportioning and mixing, reduced air incorporated into the mixture, reduced mixing time and reduced contamination of materials (Jung *et al*, 2007).

The best hand-mixing method used is stropping the material over a larger area of the pad with a flexible spatula. In a later study Stackhouse (1985) found that syringes with smaller orifices at the tip resulted in significantly fewer bubbles, as did extrusions from the second half of a syringe full of rubber impression material. The same finding was reported by Anusavice (2003) in the review of elastomeric impression materials.

Effect of latex gloves

With the advent of the Human Immunodeffiency Virus and other infectious diseases, the wearing of gloves during dental treatment is now accepted worldwide as an important step in infection prophylaxis. Most of the gloves worn by the dentist and the assistant are made of latex; this has been shown to influence the setting of the impression materials

(Baumann, 1995). Sulfur contamination from natural latex gloves has been found to inhibit the setting of the addition-cured silicone impression materials. Baumann (1995) concluded that no impression material other than polyvinylsiloxane was affected by pure latex gloves.

In an earlier study, Noonan *et al* (1985) also demonstrated that all addition-cured silicones were inhibited from polymerization by contact with rubber dam. The hypothesis is explained by a chemist for Kerr Corporation, Duncan Waller, and states that the catalyst used for polymerizing addition-cured silicones contains platinum which is converted to a complex of chlroplatinic acid during the curing reaction. Rubber dam is vulcanized rubber that contains sulfur compounds which in turn contaminate the platinum catalyst thereby inhibiting the setting reaction (Noonan *et al*, 1985).

Effect of disinfection

Infection control is of great importance in dentistry. Dental impressions become contaminated with micro-organisms from blood and saliva from the patient (Chau *et al* 1995). The potential for diseases such as HIV and Hepatitis B poses a great risk to dental staff. Hepatitis B has the ability to be transmitted in minute quantities of body fluids and remains in a virulent form outside the body for a lengthy period of time (Runnells, 1988).

It is well established that a potential exists for cross-infection as a result of contaminated dental impressions posing a hazard to laboratory personnel; and it is of paramount importance that all impressions are disinfected prior to being transferred to the laboratory (Powell *et al*, 1990).

Currently there is no agreed disinfection protocol *per se*; rinsing the impressions under water has been shown to reduce the number of micro-organisms by 90%. However, a significant number of bacteria still remain and a disinfectant protocol must be used (Blair and Wassell, 1996). The recommended disinfectant solutions include sodium hypochlorite, Gluteraldehyde, Iodophor, and Phenol.

The disinfecting solution must be an effective antimicrobial agent yet cause no adverse response to the dimensional accuracy and surface texture features of the impression material and resultant casts (Taylor *et al,* 2002).

The recommendations by the British Dental Association state that all impressions should at least undergo a disinfecting procedure by immersion in 1% sodium hypochlorite for a minimum of ten minutes. However, Blair and Wassell considered a number of solutions used for disinfecting impression materials and found no universally recognized impression disinfection protocol available (Blair and Wassell, 1996).

The duration and mode of disinfection depends on the potential of the impression to absorb water. Condensation and addition-cured silicones and polysulfide can be disinfected with all the EPA (Environmental Protection Agency) registered disinfectants without adverse dimensional changes as long as the manufacturers' recommended disinfection time is adhered to. The impression is immersed for the recommended time, rinsed and poured in the gypsum product (Anusavice, 2003).

Polyethers are susceptible to dimensional changes if immersed in excess of 10 minutes due to their hydrophilic nature. A satisfactory solution for most elastomers is 2% gluteraldehyde sprayed onto the impression until saturated. Wrapped in a disinfectant soaked towel and put in plastic bag for 10 minutes before being rinsed and poured in a gypsum product or other cast material (Blair and Wassell, 1996).

Polysulphide and silicone impression materials are immersed in gluteraldehyde, chlorine compounds, iodophors and phenolics (Blair and Wassell, 1996). Polyether impression is disinfected by immersion in 1 to 10 dilution of commercial bleach (chlorine compound). A summary of the various disinfecting solutions for the different impression materials is illustrated in Table 2.4.

Disinfectant	Irreversible hydrocolloid	Reversible hydrocolloid	Polysulphide	Silicone	Polyether
Gluteraldehyde 2%(10minutes soak time)	Not recommended	Not recommended	Yes	Yes	No
Iodophors(1:213 dilution)	Yes	Yes	Yes	Yes	No
Chlorine compounds(1:10 dilution of commercial bleach)	Yes	Yes	Yes	Yes	Yes
Complex phenolics	Not recommended	Limited data	Yes	Yes	No
Phenolics gluteraldehyde	Not recommended	Yes	Yes	Yes	No

Table 2.4 Update on disinfection of impressions, prostheses, and casts. ADA 1991 guidelines, Journal California Dental Association, 1992 (From Rosenstiel, 2006).

2.4 Dimensional accuracy analysis

Dental biomaterials have traditionally been evaluated and certified according to the requirements of standards or specifications as referred to in the American terminology (Mjor, 2007; Revised ADA specification number19.1999). Several methods have been reported to investigate the accuracy of dental impressions or of models produced from such impressions.

The American Dental Association Specification No. 19 describes a test where impressions are taken of a stainless steel die with vertical and horizontal scribed lines (Revised ADA specification No. 19, 1999). The distances between the intersecting lines are recorded with a measuring microscope and their deviation from the master steel die is considered a measure of dimensional accuracy.

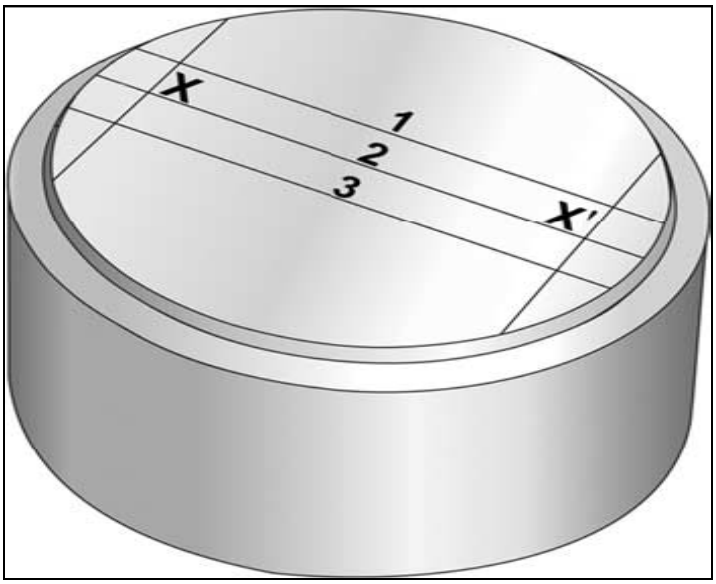

Figure 2.2 Diagrammatic representation of a stainless steel die with 3 horizontal lines (1, 2, and 3) and 2 vertical lines (X, X') (Petrie et al, 2003).

Figure 2.2 shows the stainless steel die and intersection of cross lines X and **X'** that served as the beginning and end points of the line used for the measurement of dimensional accuracy (Petrie *et al*, 2003).

Other tests use single or multiple steel die set-ups to analyze the deviations of the impressions or the stone dies from the master die (Ohsawa and Jorgensen 1983; Chen *et al*, 2004). Recently, optical 3D scanning has been proposed as another tool to investigate the accuracy of impressions and dies (Quick *et al,* 1992; Shah *et al*, 2004).

2.5 Conclusion

Major advances in impression materials and their application have occurred during the last decade, with greater emphasis being placed on rubber impression materials than on dental compound, zinc oxide-eugenol, agar and alginate. Polyether and silicone impression materials have been modified so that the working time, viscosity, and flexibility of the polyethers have been improved and, with the introduction of addition-cured silicones, their accuracy has become exceptional.

From the review of the literature it is evident that the accuracy of elastomeric impression materials on delayed and repeat pour suggests that addition-cured silicones and polyethers to a certain extent are the least affected. Addition-cured silicones are the most widely used, dimensionally accurate and stable of all materials followed by the polyethers. This stability exhibited by both these materials suggests that the impressions made from these materials do not have to be poured with gypsum products immediately.

The purpose of this study was to investigate indirectly from stone casts the long-term dimensional accuracy of standardized impressions of a stainless steel master die, similar to that described in ADA specification no 19, taken with selected elastomeric impression materials when the impressions are stored at room temperature for different storage times of 0, 3 days, 5 days and 7 days. A traveling microscope accurate to 0.01mm was be used to take the measurements on these stone casts.

CHAPTER 3

3 AIMS AND OBJECTIVES

3.1 Aim

To investigate indirectly on stone casts the long-term dimensional accuracy of standardized impressions of a stainless steel master die taken with selected elastomeric impression materials when the impressions are stored at the same environmental humidity and temperature and poured at different storage times of 0, 3 , 5 , and 7 days respectively.

3.2 Objective

To determine and recommend the most accurate and dimensionally stable impression material if the pouring of the cast is delayed.

3.3 Null hypothesis

There is no significant difference in the dimensional accuracy and surface detail score of polyether and polyvinylsiloxane impression materials if there is a delay in pouring of the models of up to one week.

CHAPTER 4

4 MATERIALS AND METHODS

4.1 Study design

This study was an *in vitro* experimental study. A pilot study was undertaken to standardize the experimental sequence of impression taking and measurements. The study was conducted in the Dental Research Institute, Tygerberg Oral Health Center at the University of the Western Cape.

4.2 Sample size

A total of sixty impressions were recorded (n=60). Twenty impressions were taken per material combination. The twenty impressions were randomly divided into four groups with five impressions per study group (Total of fifteen impressions per group) (Table 4.1 and Figure 4.1). The impressions in group I were poured immediately while the impressions in groups II, III and IV had a delayed pour after 3, 5 and 7 days respectively.

Group I	Impressions poured immediately
Group II	Impressions poured after 3 days
Group III	Impressions poured after 5 days
Group IV	Impressions poured after 7 Days

Table 4.1 Experimental groups

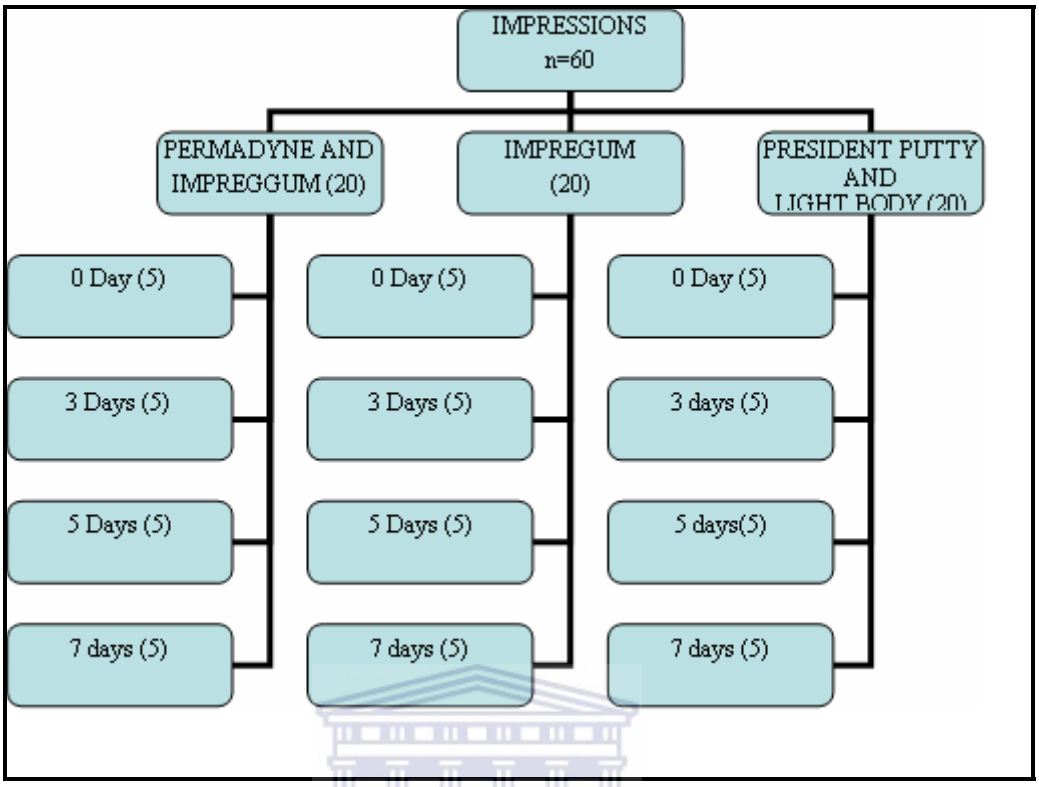

Figure 4.1 Diagrammatic representation of the impression materials used and their combinations and various groups.

4.3 Inclusion criteria

Impressions with complete reproduction of at least two of the three vertical lines were included in the study.

4.4 Exclusion criteria

Impressions with only one of the three lines reproduced and or a rough appearance were excluded from the study.

4.5 Materials

4.5.1 Experimental standardized stainless steel die

One standardized stainless steel die similar to that described in ADA specification 19, scored with 3 horizontal and 2 vertical lines was fabricated at the Stellenbosch Research laboratory for the purpose of this study. The width of the horizontal lines was 0.2mm. Two cross-points at the intersection of the vertical lines with the middle line corresponding to line 2 of the standardized die were marked x and x' and served as the

beginning and end points of the measurements for the dimensional accuracy as recommended by revised ADA specification number 19 (1999).

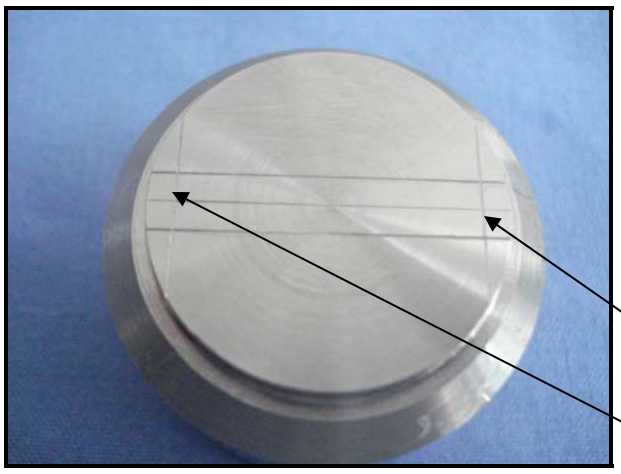

Figure 4.2 Standardized stainless steel master die fabricated for the study.

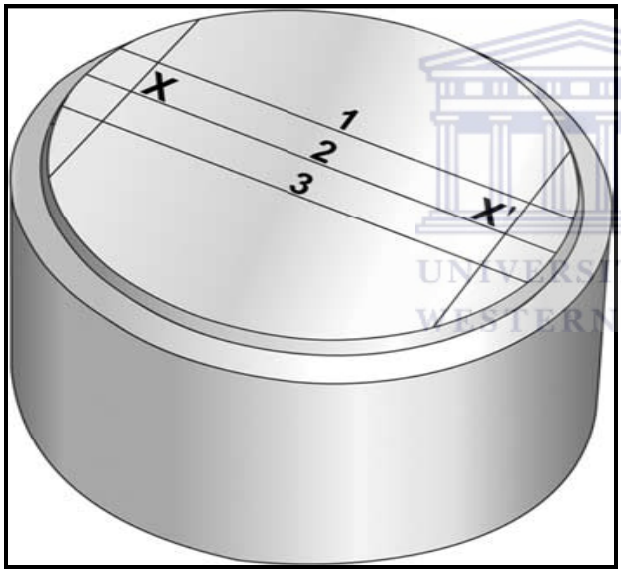

Figure 4.3 Diagrammatic representation of stainless steel die with 3 horizontal lines (1, 2, and 3) and 2 vertical lines (Petrie et al, 2003).

4.5.2 Impression Materials

Several studies have evaluated the dimensional accuracy of some of the elastomeric impression materials based on various factors with few studies dwelling on the dimensional accuracy of elastomeric impression materials with storage time (Chen *et al*, 2004; Wassell *et al*, 2002; Marco *et al*, 1998; Chew *et al.*1993; Johnson and Craig, 1985; Williams *et al*, 1984; Ohsawa and Jorgensen 1983; Lacy *et al*, 1981). Some recent products in the market have not been tested for the dimensional stability with storage time and these were included in the study. Three elastomeric impression materials that

are commonly used in the Prosthodontic department at the University of the Western Cape were tested in this study. Similar materials are used in most African countries in both private clinics and teaching institutions. The materials tested included (Table 4.2);

- **Impregum TM F (3M ESPE):** this is a medium-bodied polyether impression material for manual mixing with a mixing ratio of 7 volumes base paste to 1 volume catalyst. This material is commonly used for inlays, on-lays, crown, bridge, veneers, functional impressions, fixation impressions and implant impressions. It is the material of choice for taking optimal impressions at Tygerberg Oral Health Center Restorative Department. The manufacturer recommends that impressions made from impregum be poured not earlier than 30 minutes and not later than 14 days. The linear dimensional change is stated to be -0.3% after 24 hours according to the manufacturer (3M ESPE).
- **Permadyne (3M ESPE):** this is a low consistency polyether impression material commonly used in combination with the medium consistency polyether (Impregum TM F, 3M ESPE) as a wash impression or in a double mix impression technique.
- **Impregum "Penta" (3M ESPE):** this is a medium bodied polyether impression material for Pentamix use and is also available in the University of the Western Cape, Faculty of Dentistry Restorative Department. Due to its good handling characteristics, it is applicable for most of the impression techniques mentioned above. The linear dimensional change documented in the literature from the manufacturer is -0.3%.and is said to be stable until the 14th day before pour.

- **Colténe® President (Colténe / Whaledent AG):** this is a polyvinylsiloxane addition-cured silicone elastomer. These impression materials come in various consistencies including light body, regular body, fast light body, fast regular body and heavy body putty. The light and regular bodies are commonly used by most practitioners in dentistry and they are presented with automatic mixing devices in combination with high consistency polyvinylsiloxane putty (President, Colténe®). The main application of these materials include; putty wash impression technique; simultaneous mixing technique; relining impressions;

single phase impression technique and double arch impression technique. The documented linear dimensional percentage change is -0.2%. In addition, the manufacturer recommends maximum storage time of not more than 7 days (Colténe® / Whaledent).

Product	**Type**	**Manufacturer**	**Impression technique**	**Material's Viscosity**
Impregum	Polyether regular body	3MESPE	Single mix	Regular
Permadyne	Polyether light body	3MESPE	Double mix	Light body + regular body
President	Addition silicone	COLTENE WHALEDENT	Double mix	Light body + heavy body

Table 4.2 List of impression materials, their viscosity and impression techniques used in the study

Materials used in the study

Figure 4.4 President putty and light body with the automatic mixing device and the adhesive (Colténe® Whaledent)

Figure 4.5 Permadyne (Espe GMbH, and Germany) and its adhesive.

Figure 4.6 Impregum (Espe GmbH, Germany).

Figure 4.7 Impregum "Penta" for loading into a Pentamix machine.

Figure 4.8 Pentamix machine for automatic dispensing of impregum or Permadyne.

4.5.3 Equipment used in this study

Traveling microscope

A traveling microscope is an instrument for measuring length with a resolution of 0.05 - 0.1 mm. It is composed of a microscope mounted on two rails fixed to a supporting structure. The position of the microscope can be varied coarsely by sliding along the rails, or finely by turning a screw. Position of the microscope is read by a Vernier. The purpose of the microscope is to aim at reference marks with much higher accuracy compared with unassisted vision (http://en.wikipedia.org./wiki/main assessed on 27/07/08).

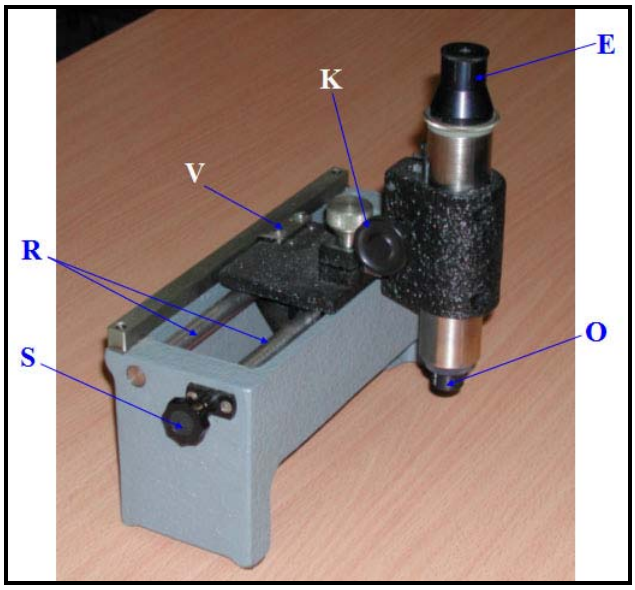

Figure 4.9 a traveling microscope. E-eyepiece, O-objective, K-knob for focusing, V-Vernier, R-rails, S-screw for fine position adjustment (http://en.wikipedia.org./wiki/main assessed on 27/07/08

Figure 4.10

Olympus U-PMTVC (UF02621) Nikon microscope with a camera and a monitor used to take standardized photographs of the impressions at 10 times magnification.

4.6 Methodology

4.6.1 Dimensional stability

The experimental stainless steel master die was covered with two wax sheets and stops were incorporated into the wax sheets. An impression of the spaced die was recorded in a polyvinylsiloxane (PVS) addition-cured silicone impression material and a wash impression done in a light body PVS. The impression was allowed to stand on the bench for 10 minutes before being removed. The resultant impression was poured in a type IV gypsum product (GC Fujirock® EP, GC Europe N.V) to fabricate four casts of the master die.

The casts were coated with a model releasing agent and light polymerizing acrylic special tray resin material (Megadenta Germany) adapted to the casts and cured for 5 minutes in a curing compartment before being removed and trimmed using an acrylic bur. The trays were left to stand on the bench for 24 hours to ensure complete setting and reduction of polymerization shrinkage associated with acrylic resins (Pagniano *et al* 1982; Goldfogel *et al* 1985). The dimensional change in acrylic resins for custom trays has been shown to vary from -0.08% to -0.4% over 24 hours, with 90% of the shrinkage occurring at 8 to10 hours and it is recommended that acrylic custom trays should not be used on the day of fabrication (Pagniano *et al* 1982; Goldfogel *et al* 1985). A total of seventy special trays were fabricated.

Before the impressions were taken, the die was ultrasonically cleaned to remove any wax residue and allowed to air dry. Care was taken to avoid contamination of the surface of the die before taking the impressions. The impressions were made using an auto mixing impression gun (Dentsply/Caulk) and prepackaged cartridges of the impression material. The cartridges were bled in compliance with the manufacturer's recommendations to ensure proper dispensing ratios.

For all the study groups the impression material was loaded into a fine-tipped impression syringe (Dentsply/Caulk) and applied to the lined areas of the die. The impression material was pushed ahead of the syringe tip. Light-bodied compounds were delivered from double-chamber cartridges fitted with static mixing tips, the medium-bodied

impregum “Penta” was machine-extruded from foil bags through a dynamic mixing head-piece (Pentamix) (Figure 4.8).

Uniform thickness of tray adhesive was applied on the tray and allowed to dry prior to the loading of the impression material (Davis *et al*, 1976; Russell and Richard, 1991) (Figure 4.11.a). To contain the material and ensure a consistent thickness of 3 mm (Anusavice, 2003; Rosenstiel *et al*, 2006), a glass slide with a 1kg weight was placed on top of the special tray as described in ADA specification 19 (1999). To simulate oral conditions the impression material was allowed to polymerize in an aqueous environment. The stainless steel die with the applied impression material was then transferred into a water bath maintained at 32°C for three minutes before being removed and left to stand on the bench for another 7 minutes; a thermometer was left in the water bath to confirm the temperature (Figure 4.12g).

Upon removal the impressions were rinsed under running tap water for 10 seconds, disinfected by immersion disinfection in 0.65% sodium hypochlorite solution for 10 minutes (Beyerle *et al*, 1994 and Shwartz *et al*, 1994) (Figure 4.12.i). The impressions were then removed from the disinfectant solution and rinsed under running water for 10 seconds and left to air dry before being poured. A total of 60 impressions were recorded, with 20 impressions for each material combination.

Twenty impressions per impression material combination that met the inclusion criteria were then randomly divided into 5 impressions per study group. Thereafter, each impression tray base was marked with a number that when matched with a master sheet corresponded to the impression material used and the respective study group. All the impressions were stored under the same conditions at room temperature on the laboratory bench. Group I: impressions were poured immediately, Group II was stored for 3 days before being poured, and Group III was stored for 5 days and Group IV for 7 days before being poured.

Type IV (GC Fujirock® EP, GC Europe N.V) gypsum was hand mixed for 10 seconds followed by 20 seconds in a vacuum mixer. The impressions were poured using a vibrator. The casts were allowed to set for 45 minutes at room temperature and then removed from the impression. The casts were left to stand on the laboratory bench for 24

hours before the measurements were recorded. A traveling microscope with accuracy to the value of 0.01millimeters was used to take the measurements (Figure 4.12.l).

The measurements for the line x to x' were repeated three times for every specimen and recorded in an Excel data sheet. The mean of the three linear measurements was then used to calculate the percentage dimensional change using the formula;

$$\text{Percentage dimensional Change} = \{(M-E)/M\} \times 100$$

(From Taylor *et al*, 2002)

Where M is the master model measurement and E is the mean of the cast measurement.

Experimental Sequence

Figure 4.12.a Master die with wax spacer ready for duplication in stone.

Figure 4.12.b cast made from the stainless steel die used to fabricate the special trays.

Figure 4.12.c Special tray acrylic resin material ready for curing.

Figure 4.12.d Auto-polymerization of the special tray in an autopolymerizing machine.

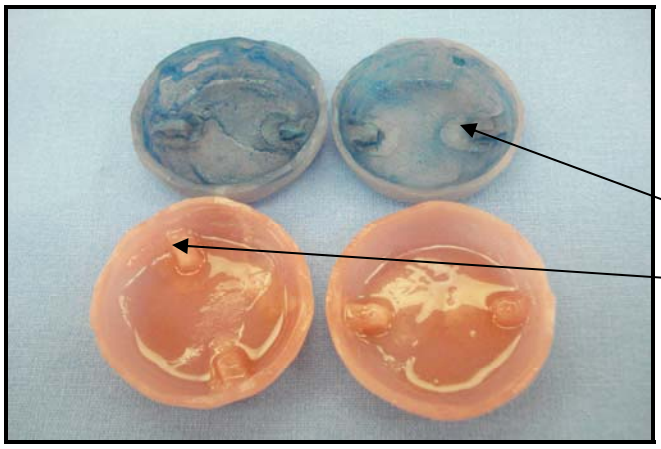

Figure 4.12.e Special trays with applied respective adhesives.

Stops on the impression surface of special trays.

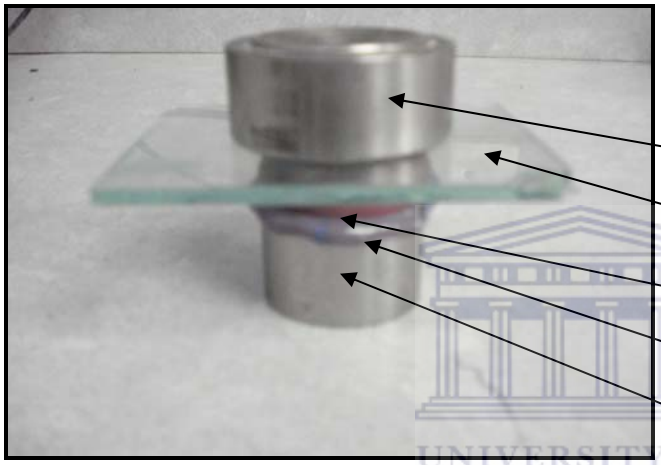

Figure 4.12.f Experimental setup.

The 1kg weight

Glass slab

Impression tray

Impression material

Experimental die

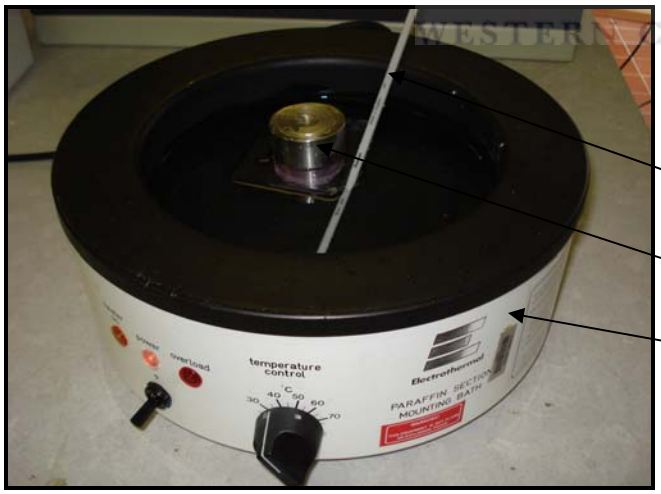

Figure 4.12.g Experimental setup in the water bath at 32°C.

Thermometer

Experimental setup

Water bath

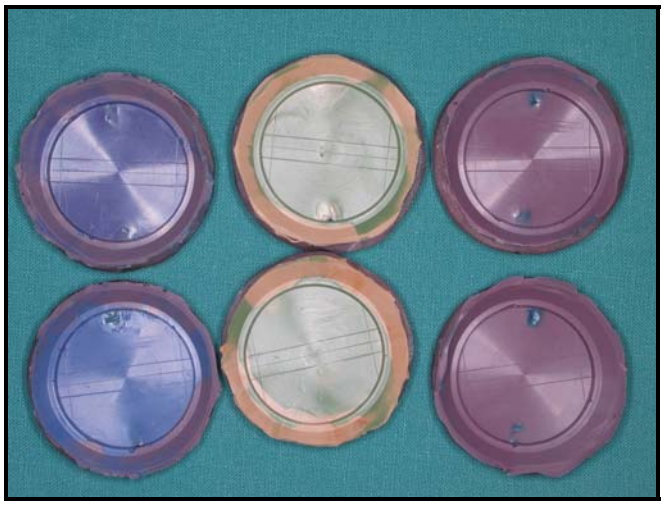

Figure 4.12.h Impressions of the master die showing the reproduction of the lines and the different materials used.

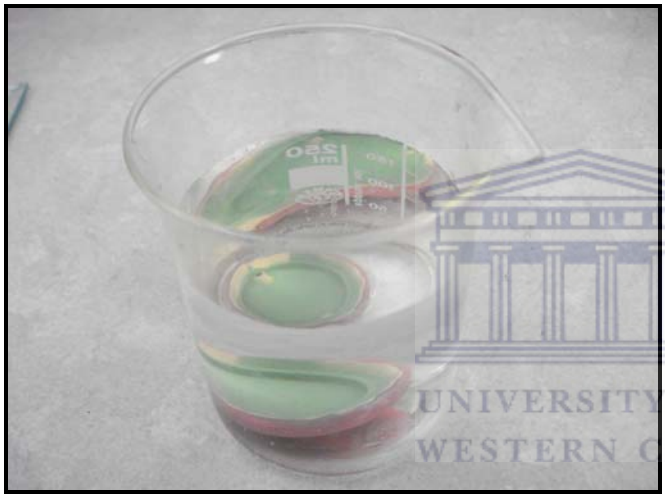

Figure 4.12.i an impression in sterilization solution of 0.65% sodium hypochlorite.

Figure 4.12.j Poured casts of the impressions.

Figure 4.12.k Labeled casts' bases from the impressions showing the materials and storage group.

Figure 4.12.l the traveling microscope used to determine dimensional accuracy based at the physics department of University of the Western Cape.

4.6.2. Surface detail reproduction

The researcher and an independent examiner evaluated surface detail reproduction. Surface detail reproduction was evaluated just before the impressions were poured in a gypsum product to evaluate the effect of storage time on surface details of the impression materials. The evaluation was an assessment of the continuity of line replication according to ADA specification 19 (1999). Surface reproduction was evaluated under a microscope at 10 times magnification and graded using the scoring system from 1 to 4 illustrated in Table 4.3.

Score 1	Denoted sharp details with continuous lines
Score 2	Continuous lines but with loss of focus
Score 3	Deterioration of both lines and details
Score 4	Rough appearance with loss of continuity

Table 4.3 Surface detail score chart.

A series of standardized photographs were taken using an Olympus U-PMTVC (UF02621) Nikon microscope with a camera and a monitor used to take standardized photographs of the impressions at 10 times magnifications (Figure 4.10). These photographs served as reference to rate the surface reproduction. The results were entered onto a data collection sheet and subjected to a Kruskal Wallis non-parametric test for pair-wise comparison (Taylor *et al*, 2002).

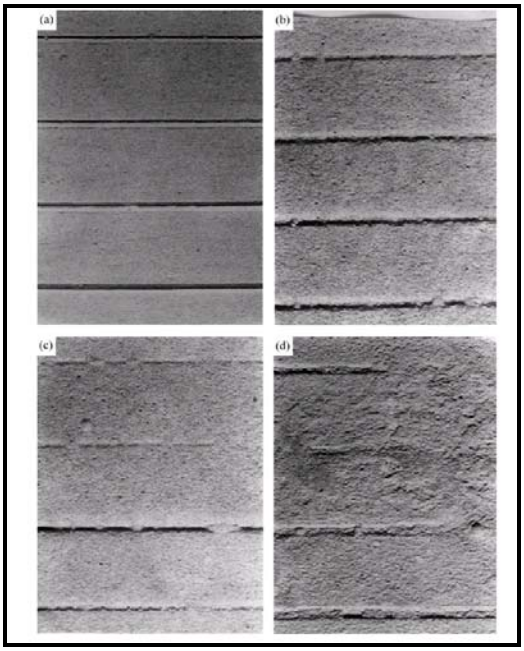

Figure 4.13 Surface detail reproduction; a-score 1; b-score 2; c-score 3 and d-score 4 (Taylor *et al*, 2002).

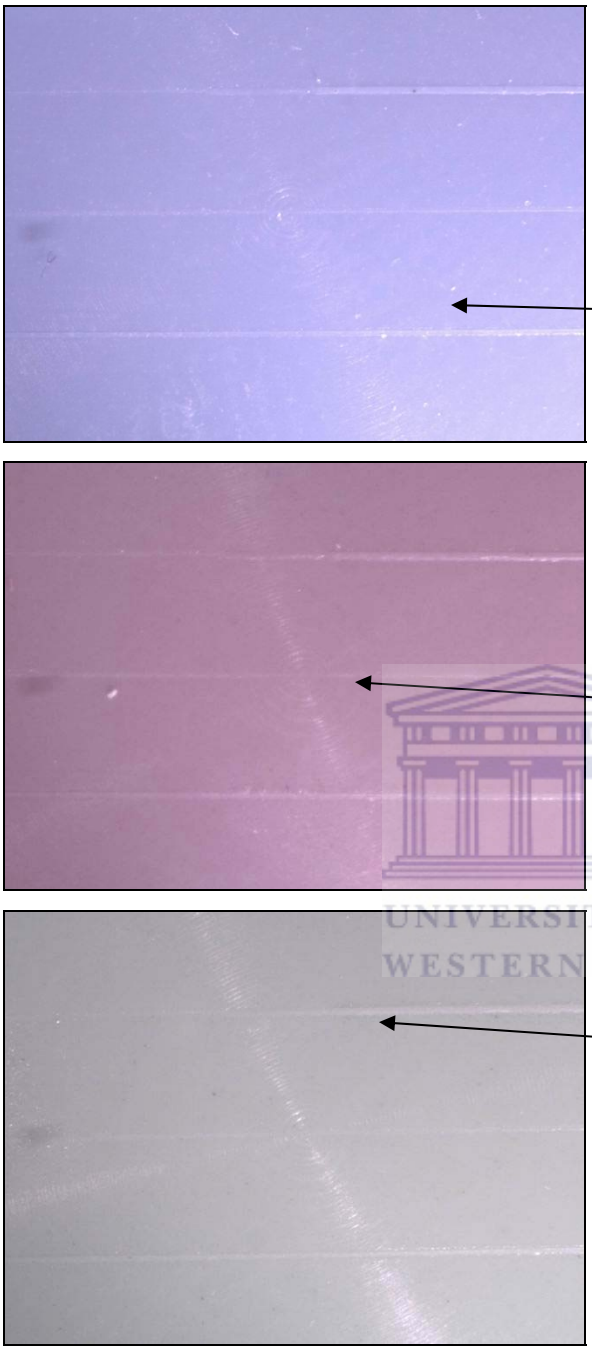

Figure 4.14 Standardized photographs of the various impressions at 10 times magnification.

Permadyne-Impregum combination (PI).

Impregum (I)

Light body President plus putty (PR)

4.7 Data analysis

The measurements and surface details scores were tabulated using an excel spreadsheet. Original scores were supplied to the statistician.

The data was analyzed using a commercially available statistical software package (SPSS 15.0, SPSS Inc.).

Data was analyzed with an analysis of variance (ANOVA) and Fisher's least significant differences for pair-wise comparison and Wilcoxon Signed Rank Sum test. For the surface detail reproduction scores the data was analyzed using a Kruskal-Wallis non-parametric test for pair-wise comparison (Significance at P Value < 0.05) between the groups.

CHAPTER 5

5 DATA ANALYSIS

The three linear readings for each experimental cast were obtained using a traveling microscope. The readings for day 0 were first recorded as baseline data. This was followed by the readings for the experimental groups stored at 3, 5, and 7 days respectively. The readings were determined by focusing the specimen under the traveling microscope's objective using the focusing knob and tuning the microscope finely by turning the focus screw. The distance between the two cross points was measured using the microscope Vernier while aiming at the reference marks with a higher accuracy and recorded manually in a data capture sheet. The measurements were then transferred to an Excel spreadsheet (Microsoft Corporation, USA) for further analysis (Appendix I).

All statistical analyses were carried out using SPSS 15.0 for windows (SPSS, Inc. Chicago, IL, and USA) and Microsoft Excel 2007 (Microsoft Corporation, USA)(Appendix III, IV and V). A CHI square statistical test was used to analyze the surface detail scores. Wilcoxon Signed Sum Rank test was used to determine statistically significant differences if any in the percentage dimensional change of the values between the baseline and the experimental groups at 0, 3, 5, and 7 days. Percentage dimensional change data was subjected to Kruskal Wallis analysis of variance (ANOVA) for pair-wise comparison to determine statistically significant differences if any at the end of the experimental period. P-values less than 0.05 were regarded as statistically significant. A negative percentage dimensional change greater than or equal to 0.5% was considered clinically observable change (ADA specification number 19; 1999).

CHAPTER 6

6 RESULTS

6.1 Results

All the measurements at immediate pour and subsequent readings at three, five and seven days were transferred to an Excel spreadsheet (Microsoft Corporation, USA). The raw data (Appendix I) refers to the three linear measurements, their mean readings and the surface detail scores over the experimental period. The percentage dimensional change was computed using the following formula:

Percentage dimensional Change (Dd) = {(M-E)/M} x 100

(From Taylor *et al*, 2002)

Where M is the master model measurement in millimeters and E is the mean of the three linear measurements of the experimental cast. The same formula was used to calculate the percentage dimensional change for all the specimens at zero, three, five and seven days with the M value remaining constant.

Appendix II represents the calculations of percentage dimensional change for all the experimental groups. American Dental Association (ADA) specification number 19 recommends a maximum negative change in dimension for addition-cured silicones to be between 0.5% and +0.1% and for polyethers to be between 0.1% and – 0.1%after a minimum of 24 hours for polyether impression materials. For the purpose of this study the percentage dimensional change beyond the limits stated above will be considered clinically significant dimensional change.

6.2 Descriptive Analysis

The mean, standard deviation, range (minimum and maximum values) for each group at zero, three, five, and seven days was calculated using Microsoft Excel (Microsoft Corporation. USA). Table 6.1, 6.2, 6.3, 6.4 and 6.5 outline the descriptive data of all the materials for the four experimental storage groups respectively.

6.2.1 Percentage dimensional change at day zero pour:

Table 6.1 summarizes the percentage dimensional change of the experimental group at immediate pour (day zero) of the impressions. The data from table 6.1 is illustrated in the Box plot graph (Figure 6.1). At immediate pour the Permadyne-Impregum combination impression material showed the highest mean percentage dimensional change of -0.315 % followed by Impregum with a mean percentage dimensional change of -0.051%. President exhibited the least percentage dimensional change with a mean of -0.011% (Table 6.1 and Figure 6.1).

Data	Impregum	Permadyne-Impregum	President
Count of study	5	5	5
Mean of Dd (%)	-0.051	-0.315	-0.011
SD of Dd	0.015	0.076	0.017
Max of Dd (%)	-0.040	0.000	0.000
Min of Dd (%)	-0.070	-0.370	-0.040

Table 6.1 Analysis of percentage dimensional change at zero day pour.

From Figure 6.1 it is evident that an outlier exists in the President experimental group. This outlier is the 11th reading which corresponds to the most percentage dimensional change that was measured in the President group at zero days (Dd = -0.040%). The next highest percentage dimensional change value in the President group is -0.011% (Appendix II).

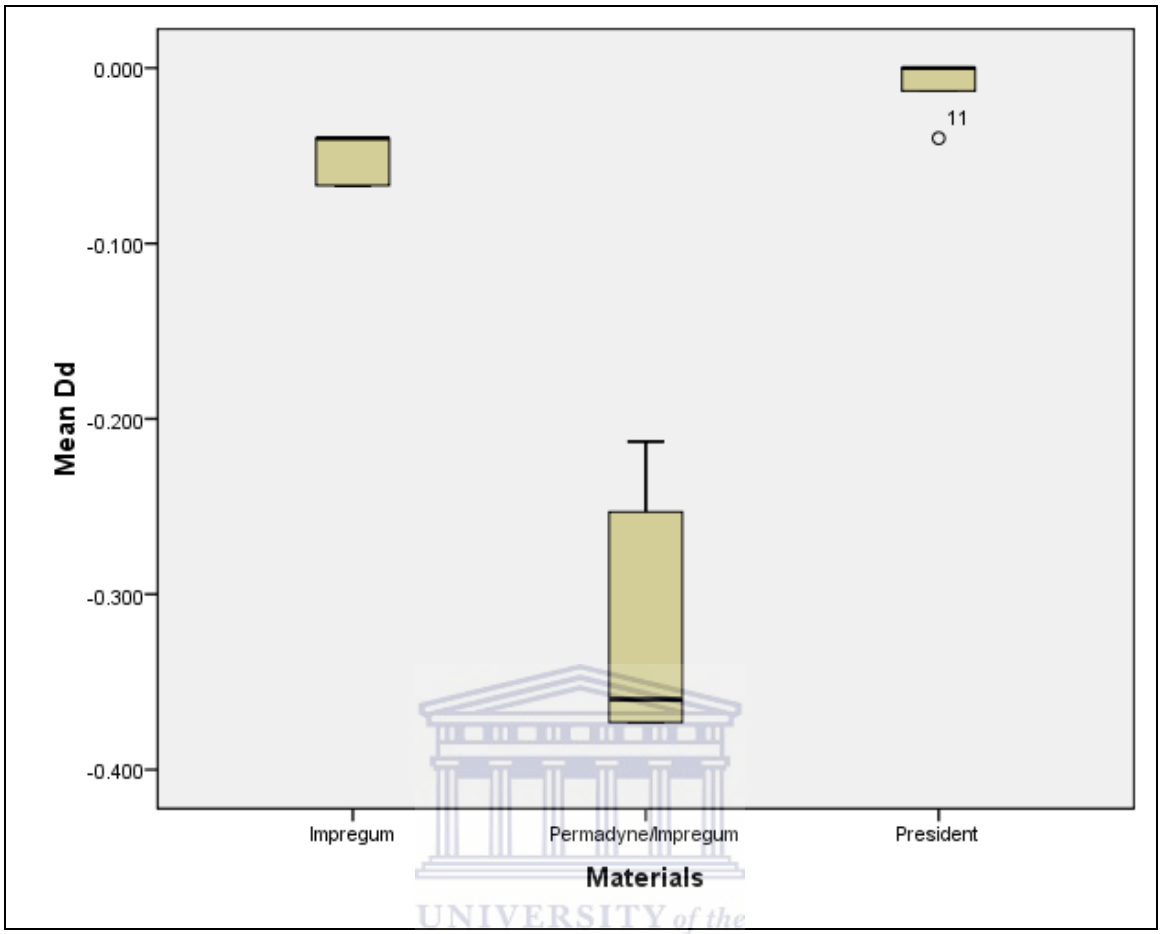

Figure 6.1 Box plot of mean percentage dimensional change at zero day pour.

6.2.2 Percentage dimensional change at three days:

The percentage dimensional change after three days for the different experimental impression material groups are tabulated in Table 6.2. The data from Table 6.2 are graphically illustrated in the Box plot graph in Figure 6.2. At three days President showed the highest mean percentage dimensional change of -0.067% followed by Permadyne-Impregum combination with a mean percentage dimensional change of -0.045%. Impregum exhibited the least percentage dimensional change with a mean of -0.005% (Table 6.2 and Figure 6.2).

However, the entire percentage dimensional changes that occurred at three days pour would be clinically acceptable as the negative percentage dimensional change was below -0.5% as stated in the ADA specifications for elastomeric impression materials guidelines (ADA specification number 19. 1999).

Data	Impregum	Permadyne-Impregum	President
Count of study	5	5	5
Mean of Dd (%)	-0.005	-0.045	-0.067
SD of Dd	0.033	0.026	0.031
Max of Dd (%)	0.000	-0.010	-0.040
Min of Dd (%)	-0.040	-0.080	-0.120

Table 6.2 Analysis of percentage dimensional change at three days pour.

It is evident from figure 6.2 that an outlier exists that relates to the 11th reading in the President experimental group (Appendix II). This value corresponds to the maximum percentage dimensional change that occurred at three days from baseline in the President experimental group that was stored for three days (Dd of -0.120%). The rest of the readings for President computed to a narrow spread around the mean percentage dimensional change of -0.067%.

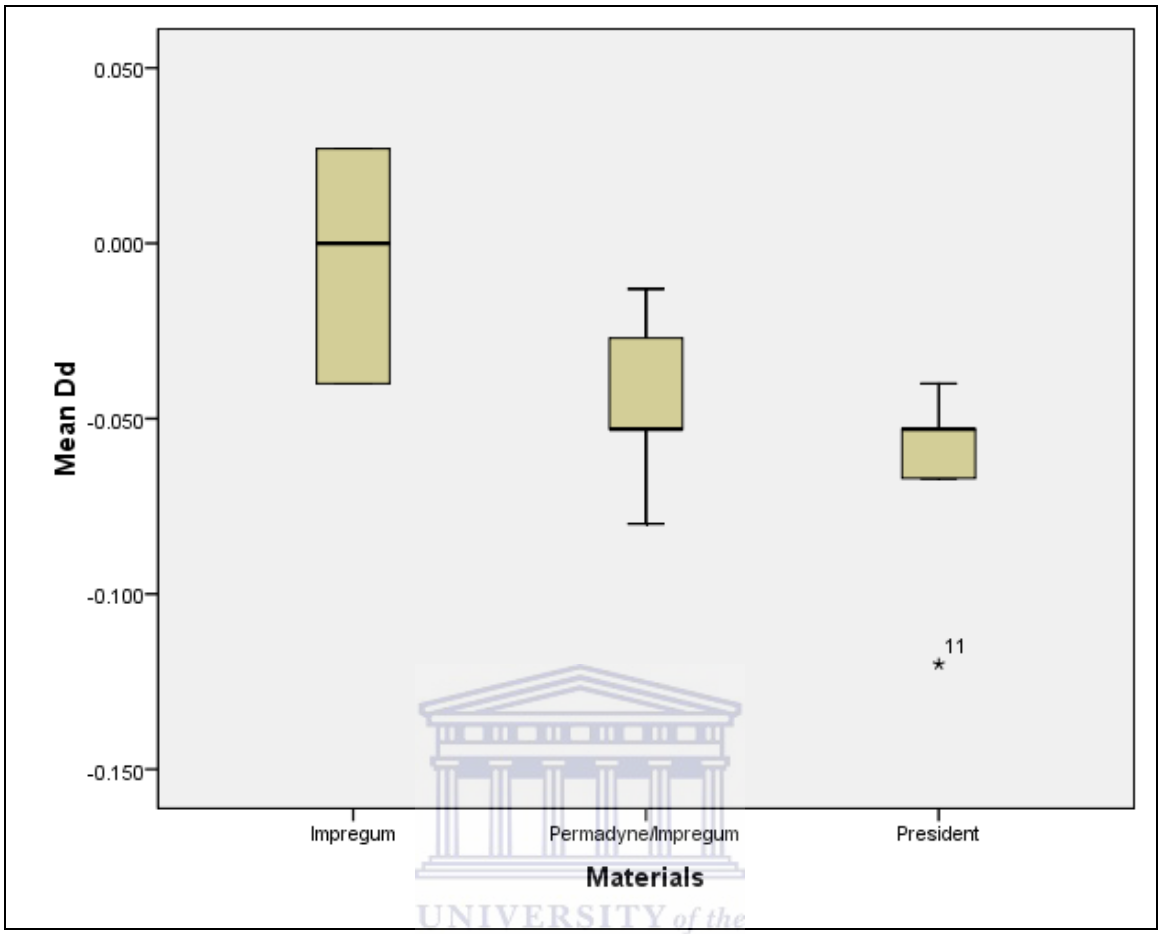

Figure 6.2 Box plot of mean percentage dimensional change at three days pour.

6.2.3 Percentage dimensional change at five days:

The percentage dimensional change measured at five days for the different experimental impression materials is tabulated in Table 6.3 and depicted graphically in Figure 6.3. At five days the Permadyne-Impregum combination showed the greatest percentage dimensional change amongst the experimental material groups with a mean of -0.107 % with a wide spread around the mean for the rest of its percentage dimensional change values. Impregum impressions demonstrated the least percentage dimensional change when cast on the fifth day with a mean of -0.011% and with near zero variation around the mean for the rest of its values. President showed a dramatic decrease in dimensional change at day five with a mean of -0.032% nearing its reading at immediate pour with a narrow spread around the mean for the rest of its values. However, all the values were within the stipulated acceptable limits.

Data	Impregum	Permadyne-Impregum	President
Count of study	5	5	5
Mean of Dd (%)	-0.011	-0.107	-0.032
SD of Dd	0.048	0.275	0.037
Max of Dd (%)	0.053	-0.010	0.000
Min of Dd (%)	-0.080	-0.410	-0.090

Table 6.3 Analysis of percentage dimensional change at five days pour.

The maximum dimensional change reading computed for this group is -0.107% and was recorded for the Permadyne-Impregum combination and remained the highest amongst the experimental groups for the second time. However the value of change at five days was lower than the value recorded at day zero by a considerable margin of 0.208%.

Outliers corresponding to the 1st and 5th reading for Impregum experimental group and the 11th reading for the President experimental group existed (Figure 6.3). These values correspond to the minimum and maximum dimensional change that occurred in the

Impregum experimental group at five days from baseline (-0.080% and + 0.053%). respectively) and for President (-0.090%). The rest of the readings computed to a narrow spread around the mean of Dd of -0.01% and -0.032% for Impregum and President experimental group respectively.

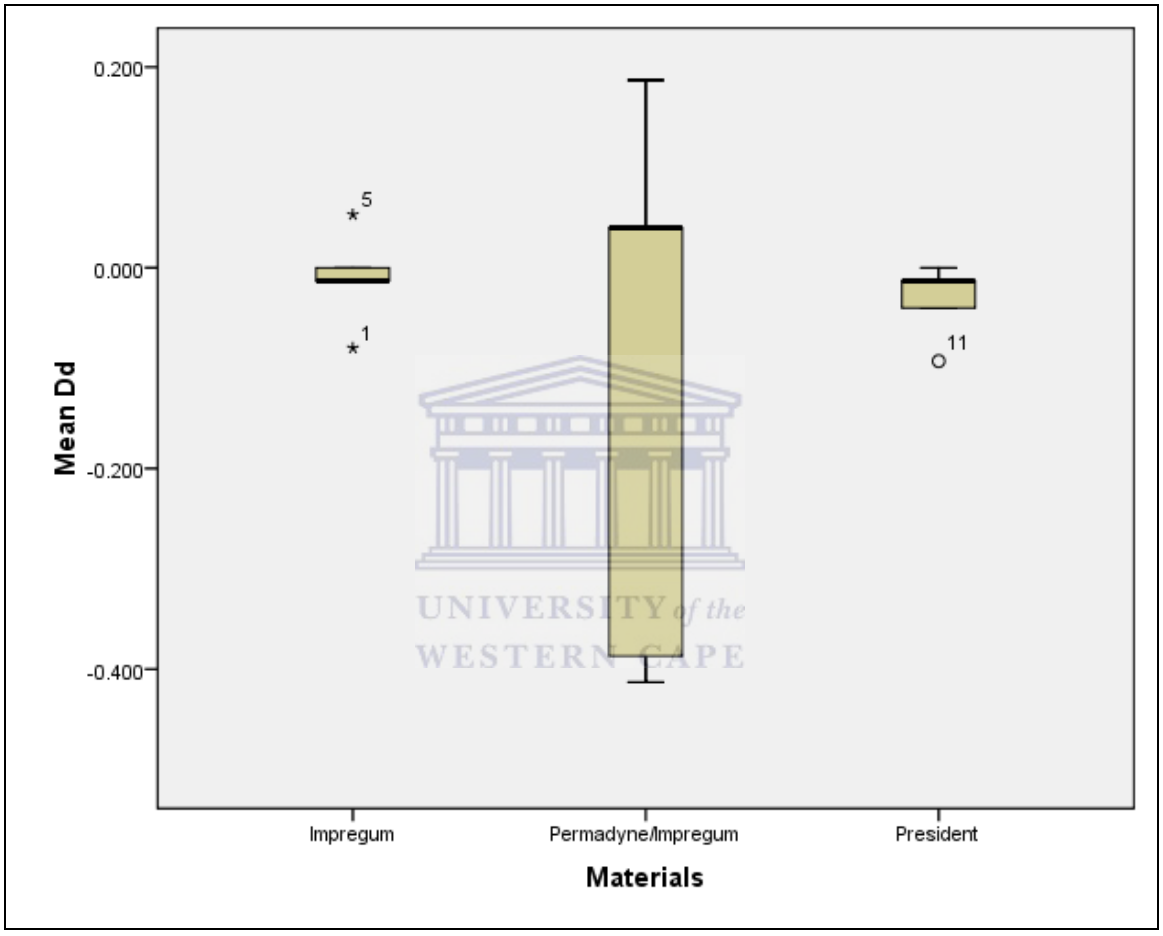

Figure 6.3 Box plot depicting the mean percentage dimensional change at five days pour.

6.2.4 Percentage dimensional change at seven days:

The final reading for percentage dimensional change measured after seven days for the different experimental impression materials tabulated in Table 6.4 demonstrated the highest positive percentage dimensional change for the Permadyne-Impregum combination with a mean of +0.163%, followed by +0.096% for Impregum.

President showed the greatest negative dimensional change ever compared to the readings in the initial three experimental study groups with a mean percentage dimension change of -0.125%. However, all the computed values for this group were within the stipulated clinically perceptible limit except for the Permadyne-Impregum combination group whose value was above the recommended value of +0.1% (ADA Specification No 19:1999).

Data	Impregum	Permadyne-Impregum	President
Count of study	5	5	5
Mean of Dd (%)	0.096	0.163	-0.125
SD of Dd	0.175	0.170	0.037
Max of Dd (%)	0.430	0.350	-0.240
Min of Dd (%)	-0.030	-0.040	-0.030

Table 6.4 Analysis of percentage dimensional change at seven days pour.

At seven days no outlier existed and all values were computed around the mean for all the experimental material groups (Mean Dd of +0.096%, +0.163 and -0.125% respectively) for the Impregum, Permadyne-Impregum combination and President experimental groups respectively (Figure 6.4).

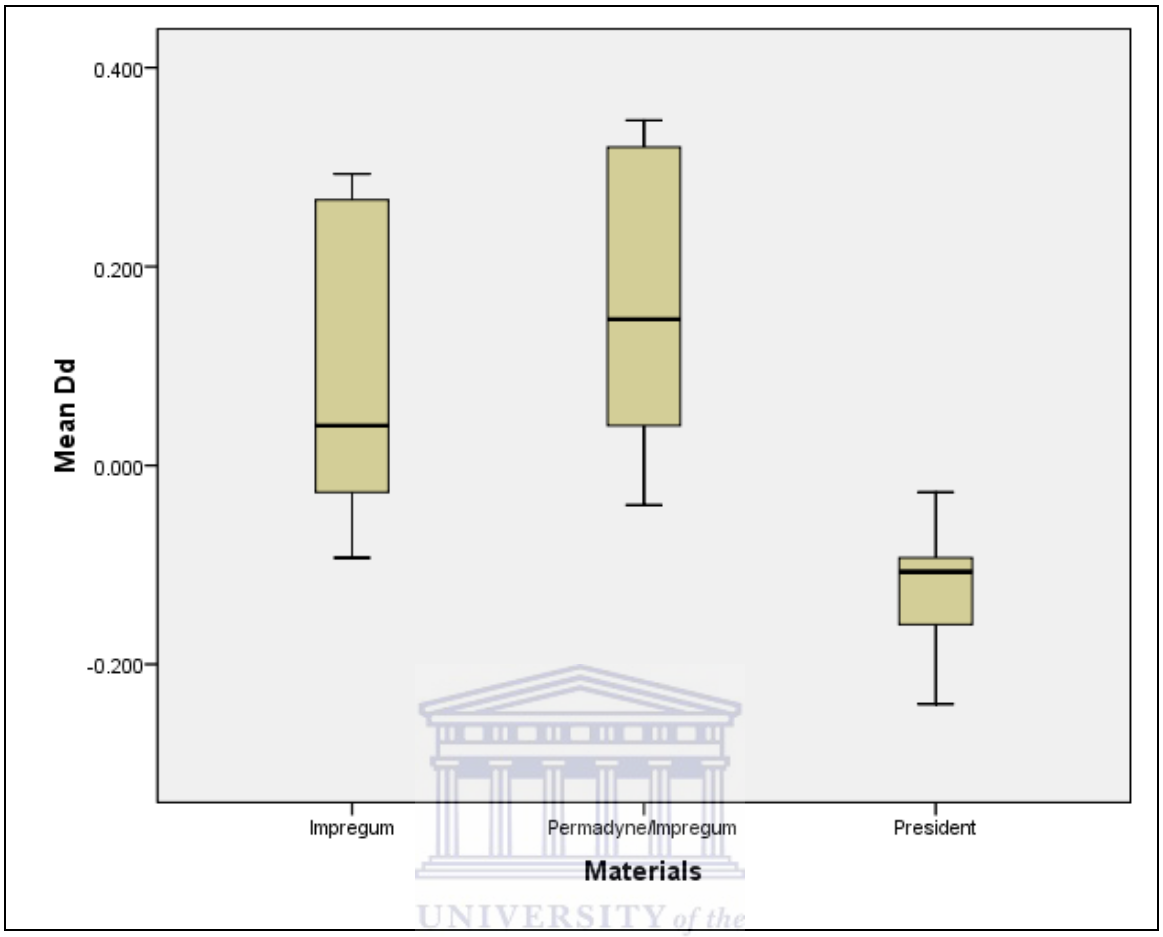

Figure 6.4 Box plot depicting the mean percentage dimensional change at seven days pour.

6.3 Degree of percentage dimensional change

The degree of percentage dimensional change during the experimental period for each group of materials is summarized in Table 6.5. Figure 6.5a, 6.5b and 6.5c; depict the trend for the Impregum, the Permadyne-Impregum combination and the President material groups respectively with time. Table 6.5 and Figure 6.6 outlines the mean dimensional percentage change (Mean Dd) for each experimental group at zero, three, five and seven days after pouring of the casts.

Mean of Dd per study groups (%)				
Material	**0 days**	**3 days**	**5 days**	**7 days**
Impregum	-0.051	-0.005	-0.011	0.096
Permadyne-Impregum	-0.315	-0.045	-0.107	0.163
President	-0.011	-0.067	-0.032	-0.125

Table 6.5 The mean percentage dimensional change at 0, 3, 5, and 7 days pour as reflected by the mean Dd.

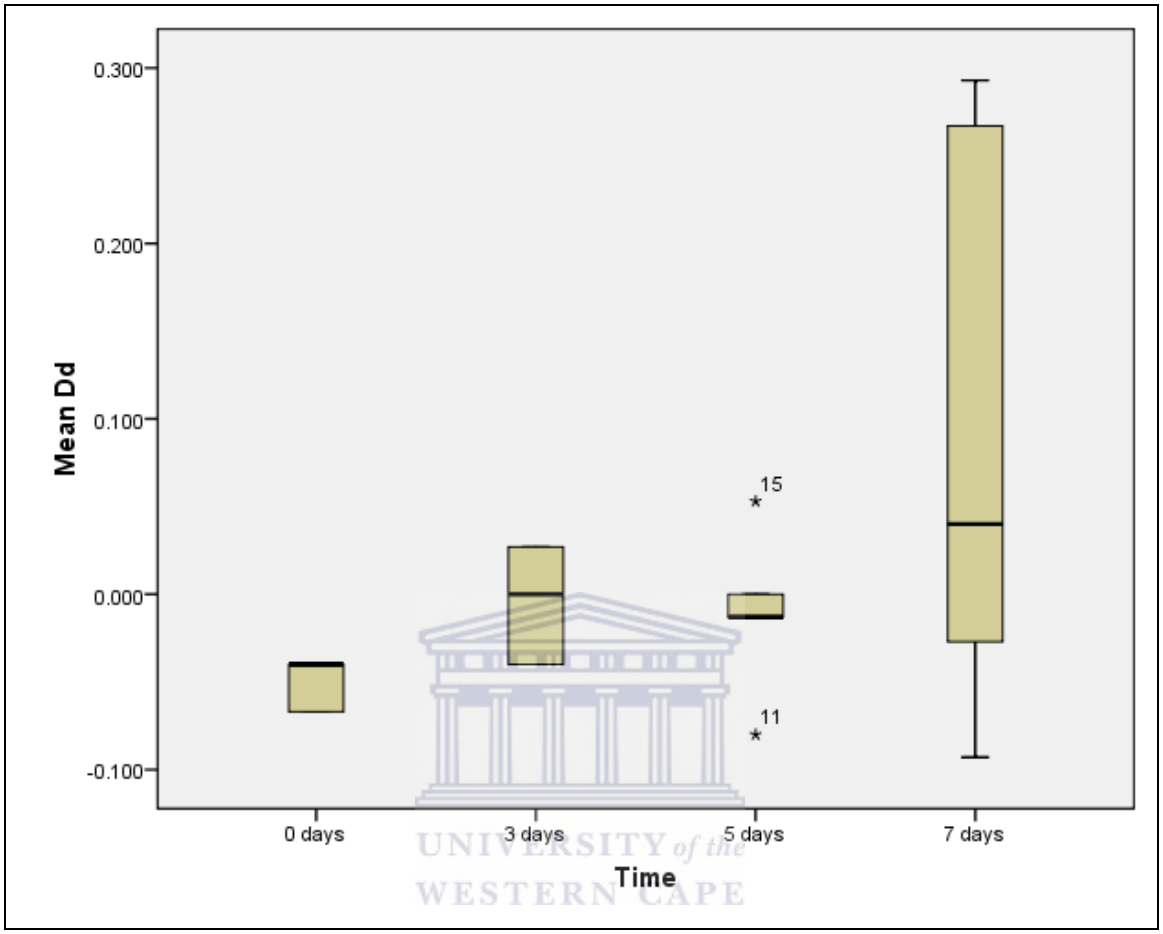

Figure 6.5 a. Box plot depicting mean percentage dimensional change (Dd) for Impregum with time.

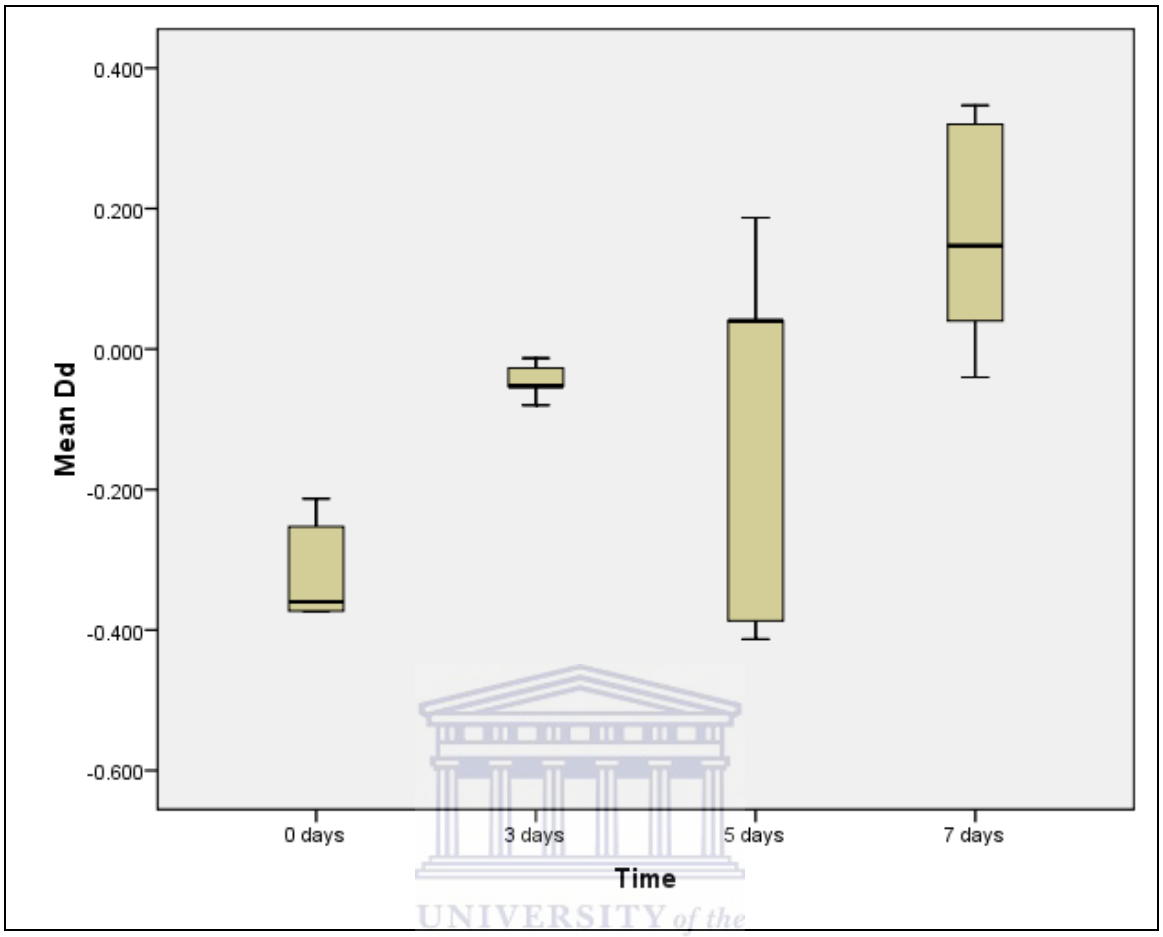

Figure 6.5 b. Box plot depicting mean percentage dimensional change (Dd) for Permadyne-Impregum combination with time.

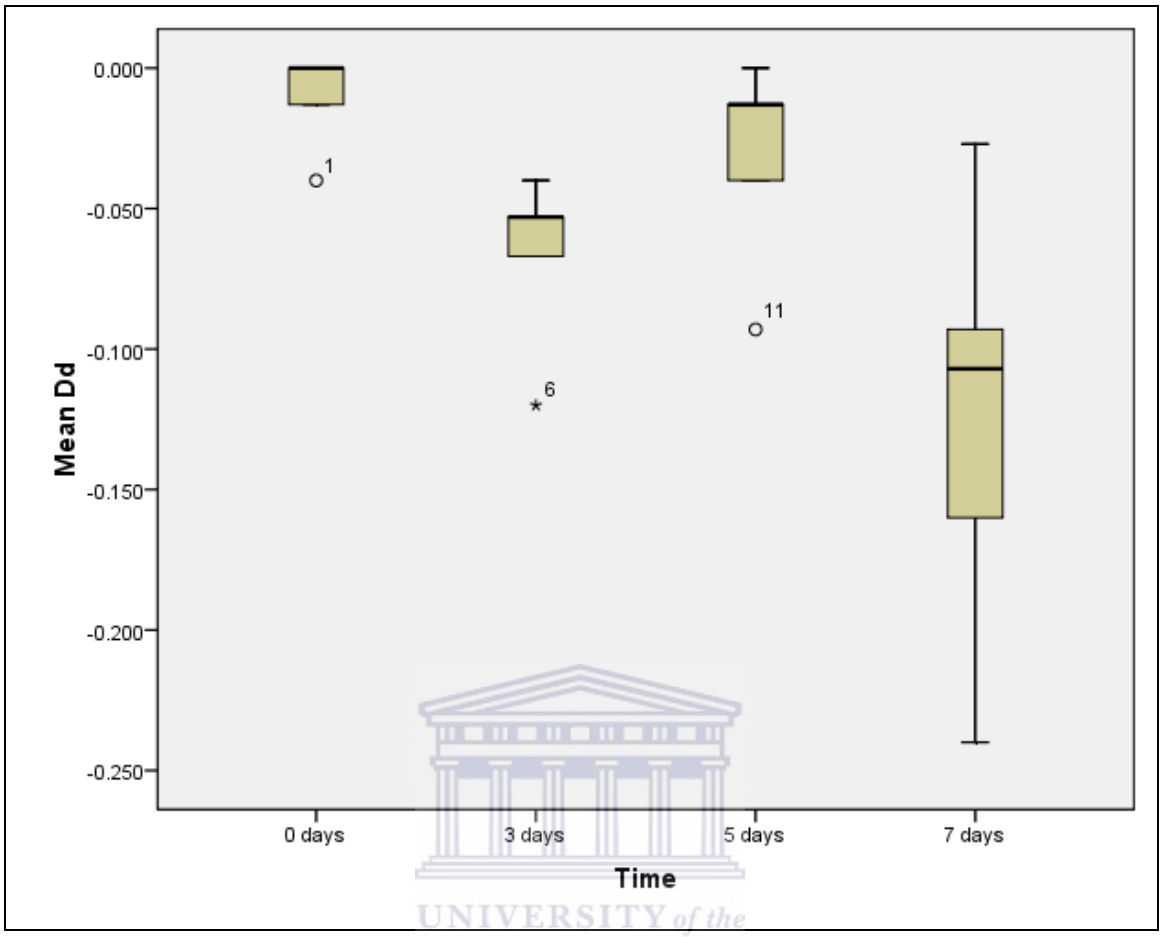

Figure 6.5 c. Box plot depicting mean percentage dimensional change (Dd) for President with time.

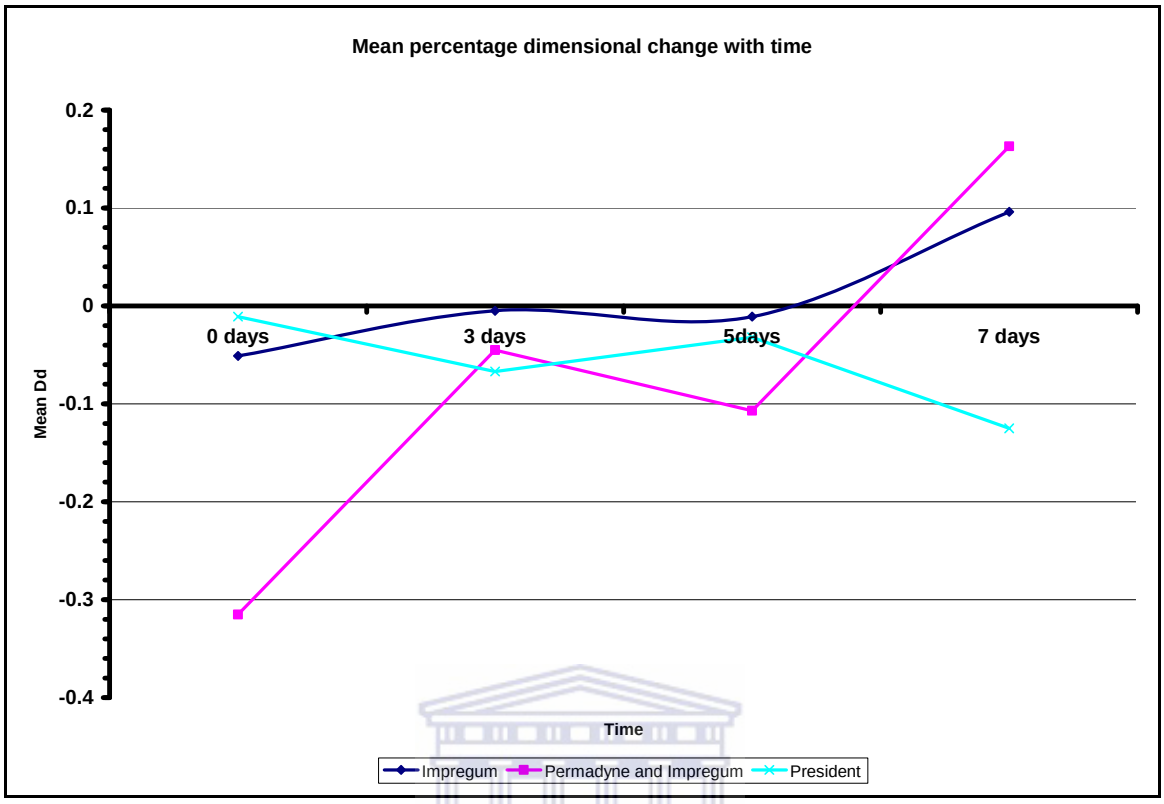

Figure 6.6 Line graph demonstrating mean percentage dimensional change over time.

6.4 Differences in percentage dimensional change within study groups

Table 6.6 and Figure 6.7 represent the differences in the mean percentage dimensional change that was measured from day zero to day three, day three to day five, and finally from day five to day seven. These measurements demonstrate the difference in percentage dimensional change within the experimental study groups. It is evident from Table 6.6 that a marked percentage dimensional change occurred between day zero and day three ranging from -0.056% to +0.270% as well as from day 5 to day 7 (-0.083% to +0.270%). This could be clinically significant as the acceptable range of percentage dimensional change (Dd) is -0.5% to + 0.1% according to ADA specification number 19: 1999.

Differences in mean Dd within days			
Materials	(Day 3-Day 0)	(Day 5-Day 3)	(Day 7-Day 5)
Impregum	+0.046	-0.006	+0.085
Permadyne-Impregum	+0.270	-0.062	+0.270
President	-0.056	+0.035	-0.083

Table 6.6 Differences in the mean percentage dimensional change at the observation periods

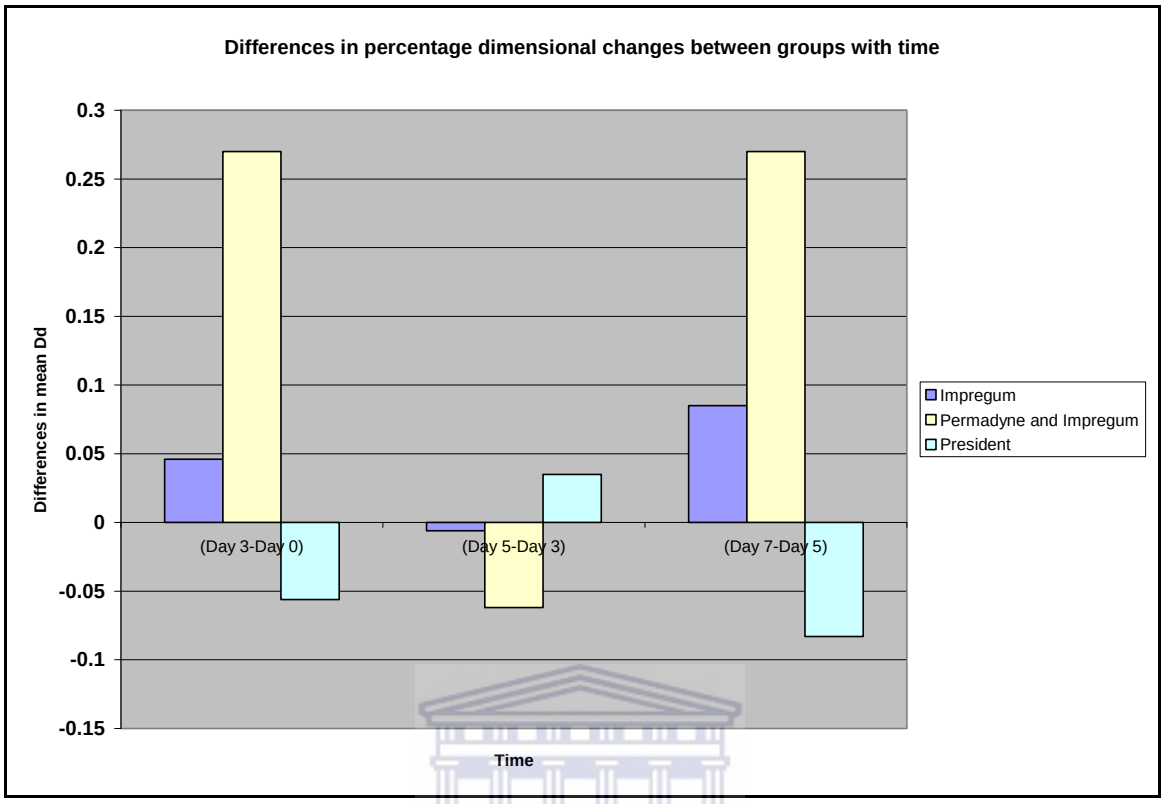

Figure 6.7 Bar graph depicting the mean Dd differences within study groups.

It is evident from Figure 6.7 that all the experimental material groups exhibited the least dimensional change between day three and day five with Impregum exhibiting the least change followed by President and thereafter the Permadyne-Impregum combination. The greatest change was observed between the 5th and the 7th day for Impregum and President. The Permadyne-Impregum combination exhibited the highest changes between day zero and day three as well as between day five and day seven.

6.5 Surface detail reproduction score results

Tables 6.7, 6.8 and 6.9 and Figures 6.8, 6.9, and 6.10 depict the surface detail scores for the various materials in the different groups. Table 6.9 gives the overall surface detail score for all the study groups. Surface detail reproduction was assessed by scoring standardized photographs of the impression surfaces at 10 times magnification using a Nikon microscope with a camera mounted and a monitor to capture and store the photographs in soft copy. The scoring system used graded the photographs from grade 1 to 4 with grade 1 being the best score, grades 1 and 2 being clinically acceptable and grades 3 and 4 being clinically unacceptable. This was done by the researcher and an independent examiner. The inter- and intra observer errors were minimized by assessing 10 samples at random after the initial assessment and comparing these results with the initial readings. The difference between the two readings was insignificant.

6.5.1 Surface detail score for Impregum with time:

Impregum impression material had a total of 6 surface detail scores of 1 and 14 surface detail scores of 2. This is depicted in Table 6.7 and graphically presented in Figure 6.8. There was no surface detail score of 3 or 4.

Impregum material group					
Study groups	0 days	3 days	5 days	7 days	Total
surface detail score 1	3	3	0	0	6
surface detail score 2	2	2	5	5	14
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20

Table 6.7 Surface detail score for impregum impression material

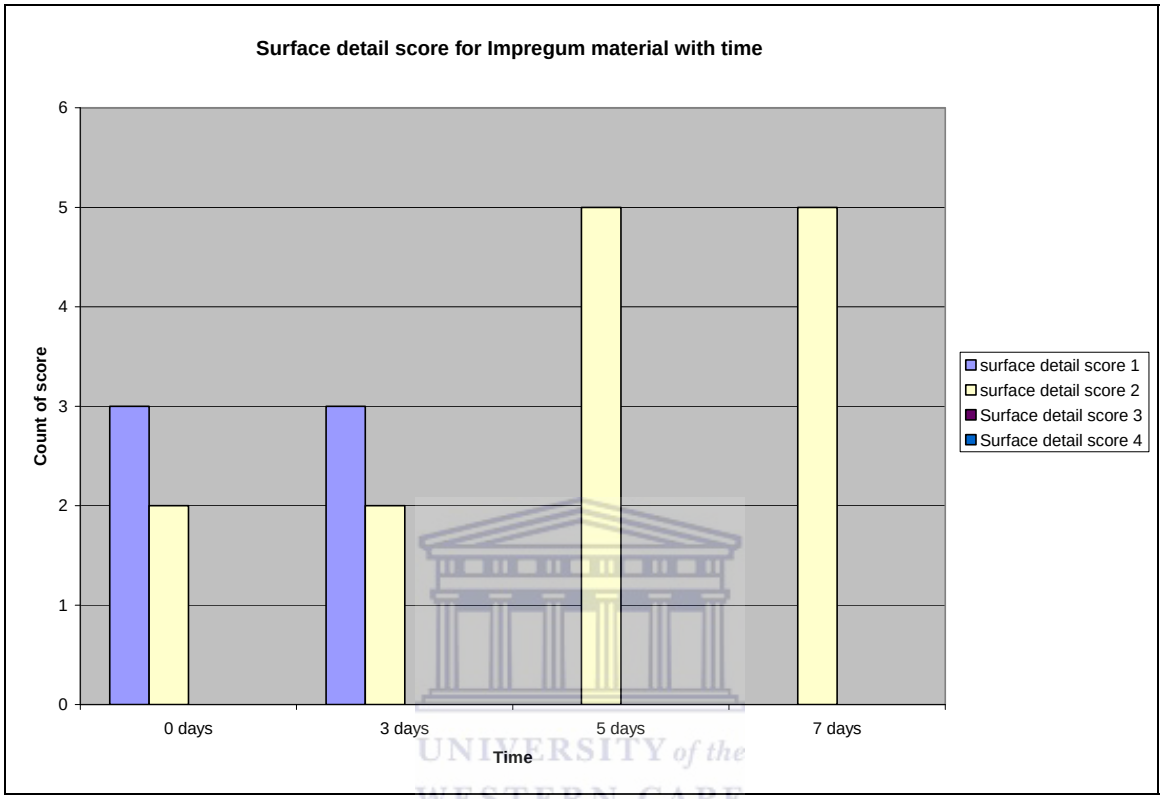

Figure 6.8 Bar graph showing the surface detail score for impregum impression material with time.

6.5.2 Surface detail score for Permadyne-Impregum combination:

Table 6.8 and Figure 6.9 depict the surface detail score for the Permadyne-Impregum combination material experimental group. The total surface detail score of 1 was at a high of 16 and surface detail score 2 was at a low of 4. This group of material had the highest surface detail score value for score 1 (16).

Permadyne-Impregum combination material group					
Study groups	**0 days**	**3 days**	**5 days**	**7 days**	**Total**
surface detail score 1	2	4	5	5	16
surface detail score 2	3	1	0	0	4
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20

Table 6.8 Surface detail score for Permadyne-Impregum combination with time.

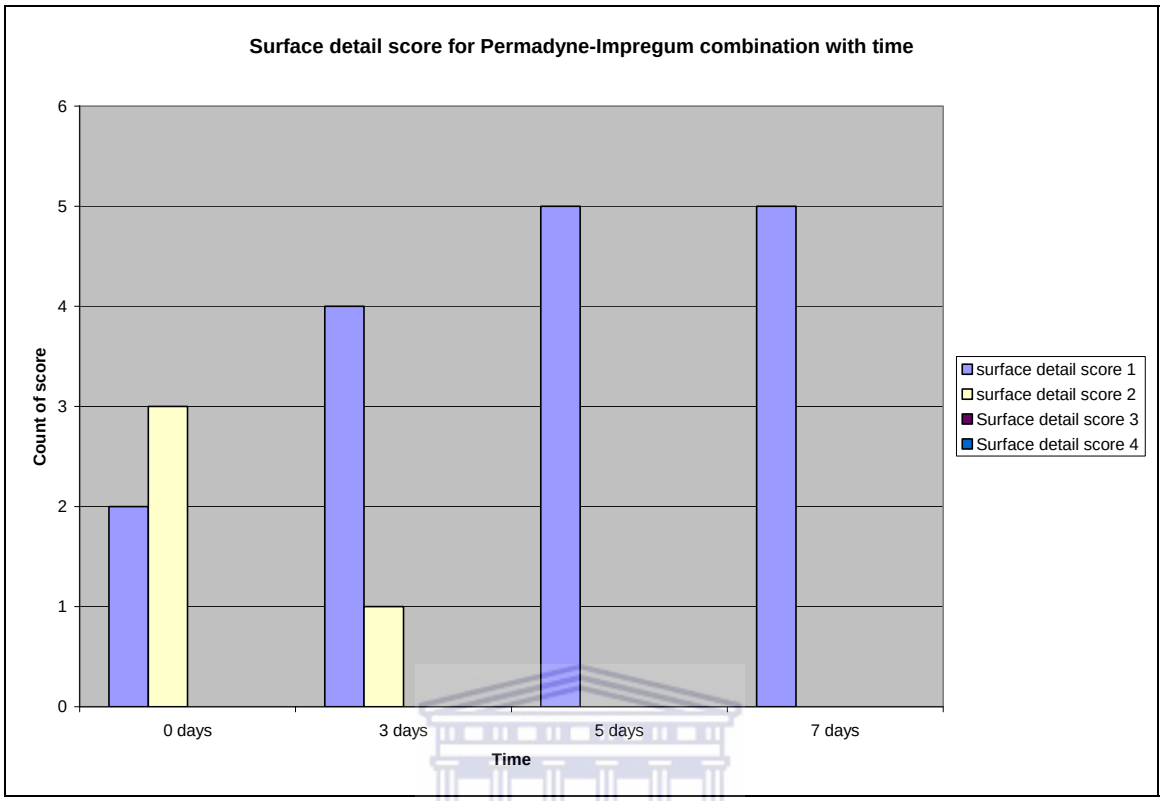

Figure 6.9 Bar graph showing the surface detail scores for Permadyne-Impregum combination with time.

6.5.3 Surface detail score for President:

The experimental group for President impression material had the least surface detail score of 1 (2), as depicted in Table 6.9 and Figure 6.10. The highest surface detail score of 2 was recorded for this group with a total of 18 scores.

President material group					
Study groups	0 days	3 days	5 days	7 days	Total
surface detail score 1	2	0	0	0	2
surface detail score 2	3	5	5	5	18
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20

Table 6.9 Analysis of surface detail score for President impression material with time.

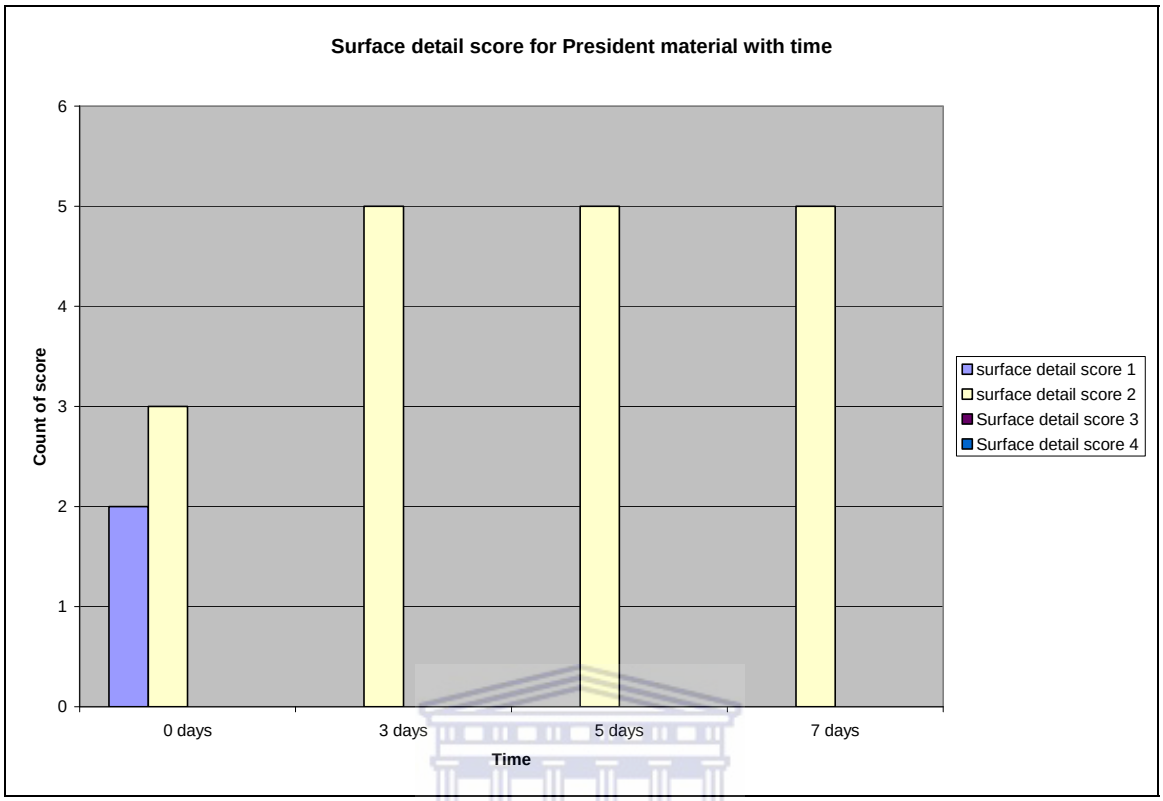

Figure 6.10 Bar graph depicting surface detail scores for President impression material with time.

6.5.4 Composite surface detail score for all three Impression Materials:

Table 6.10 and Figure 6.11 show the overall surface detail score of the casts poured from all the impression materials at zero, three, five and seven days. The total for the surface detail score of 1 was 24 out of a maximum of 60 experimental samples. The surface detail score of 2 was recorded for 36 out of a total of 60 experimental samples. Casts poured at zero and three days had the highest surface detail score of 1 with a value of 7 each followed by casts poured at five and seven days with a value of 5 each.

Study group	0 day	3rd day	5th day	7th day	Total
Surface detail score 1	7	7	5	5	24
Surface detail score 2	8	8	10	10	36
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	15	15	15	15	60

Table 6.10 Surface detail score per study group.

Figure 6.11 graphically depicts the number of surface detail score of 1 and score of 2 for casts poured at zero day, third day, fifth day and seventh day.

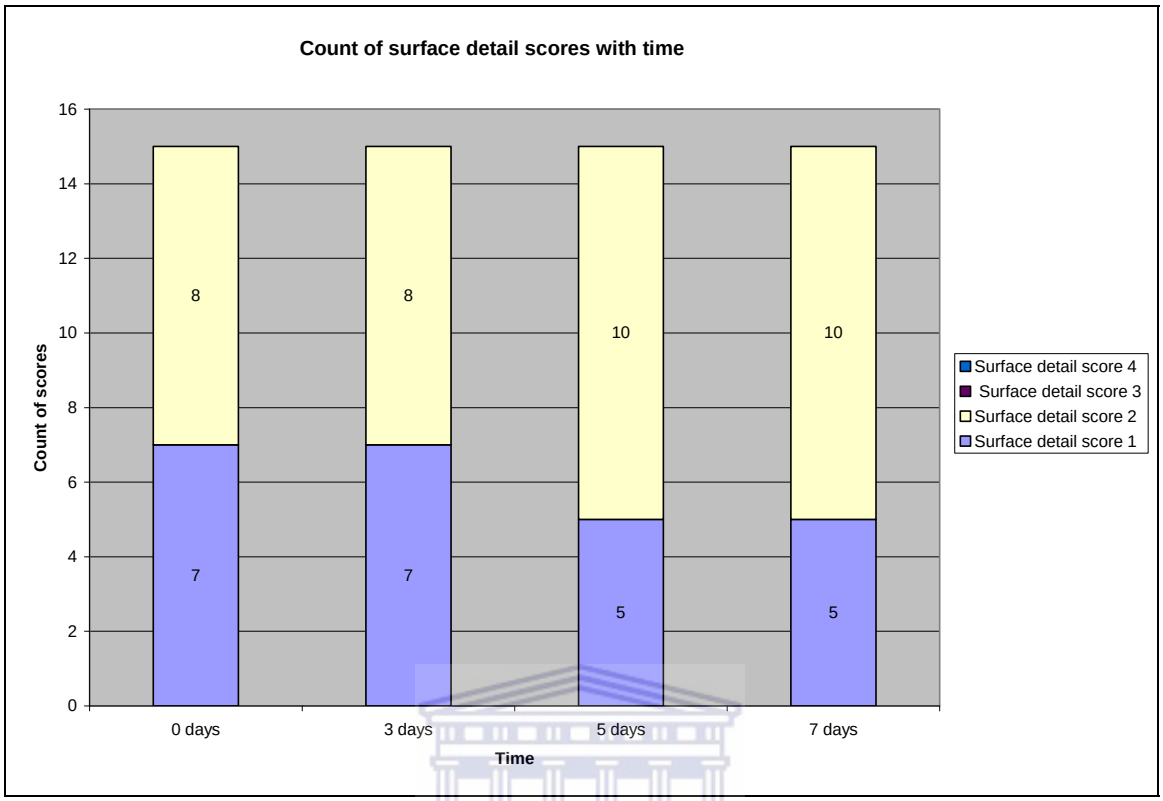

Figure 6.11 Composite Bar graph showing the surface detail score for the counts of scores per study group.

6.6 Statistical analysis

6.6.1 Statistical analysis for surface detail score

Impregum:

A Chi-Square statistical test was done to determine if the differences in surface detail scores for Impregum impression material poured at zero, three, five and seven days was statistically significant (*P-Value= 0.0356*). This indicates that the difference in surface detail scores with time is statistically significant (Appendix III).

Permadyne-Impregum combination:

Chi-Square statistical test was done to ascertain whether there was any statistically significant difference in surface detail scores of casts poured at zero, three, five and seven days (*P-Value=0.0576*). This indicates that the difference in surface detail score with time is not statistically significant for this combination of materials (Appendix III).

President:

Chi-Square statistical test was used to ascertain whether there was any statistically significant difference in surface detail scores with time (*P-Value=0.0833*). This indicates that the difference in surface detail scores with time is not statistically significant for this experimental group of materials (Appendix III).

Overall surface detail score:

Chi-square statistical test was done to investigate whether the three materials are the same as pertains to surface detail reproduction (Table 6.11 and Figure 6.12). The risk that we make a mistake when saying that the three materials are different is equal to (*1.97966E-05*). This is equivalent to a P- Value of 0.00001980 which is very close to zero. This implies that the difference as regards surface detail of casts poured from the different impression materials is statistically significant.

Figure 6.12 depicts the proportion of the various scores with score 1 showing a high of 67% for the Permadyne-Impregum combination followed by 25% for Impregum and 8% for President impression materials, while score 2 has an almost equal amount for President (50%) and Impregum (39%) with a low for the Permadyne-Impregum combination (11%).

Score of 1 is best	Impregum	Permadyne-Impregum combination	President (Light body and Putty)	Total
Score 1	6	16	2	24
Score 2	14	4	18	36
Score 3	0	0	0	0
Score 4	0	0	0	0
Total	20	20	20	60
Proportion of Score 1	30.00%	80.00%	10.00%	
Proportion of Score 2	70.00%	20.00%	90.00%	
Test Statistic Chi-Square = 21.6667 P-Value = 0 Df = 2 Degree of freedom				

Table 6.11 Statistical analysis for overall surface detail scores.

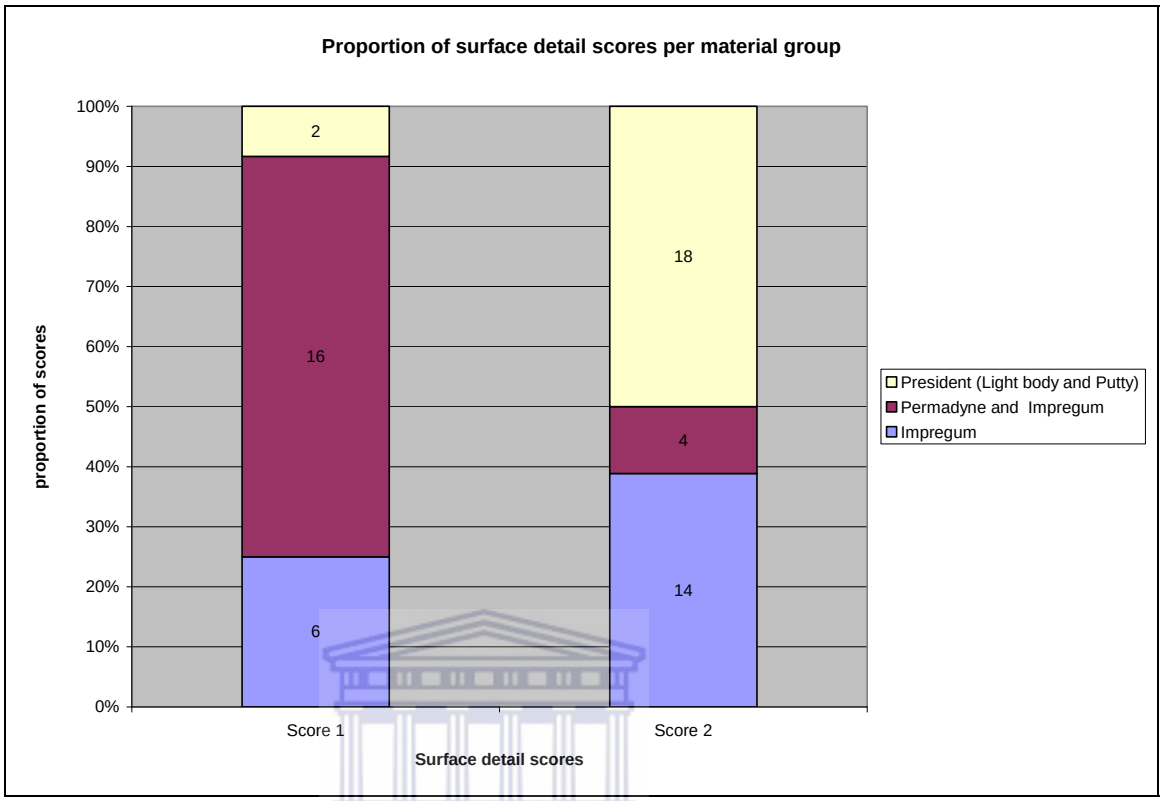

Figure 6.12 Proportion of scores for overall surface detail scores with time.

6.6.2 Statistical analysis for percentage dimension change (Dd)

The measurements of each experimental group were then analyzed with non-parametric paired test, Wilcoxon Signed Rank sum test. This test compared the differences between the percentage dimensional change values within each impression material group at zero, three, five, and seven days pour (Appendix IV).Table 6.12 summarizes the results of the Wilcoxon Signed Rank Sum test

Group	Mean 0 Day pour (Dd1)	Mean 3 Day pour (Dd 2)	P-value	Mean 5 Day pour (Dd3)	P-value	Mean 7 Day pour (Dd4)	P-value
Impregum	-0.051	-0.005	0.041*	-0.011	0.080	+0.096	0.080
Permadyne-Impregum	-0.315	-0.045	0.001*	-0.107	0.223	+0.163	0.043*
President	-0.011	-0.067	0.042*	-0.032	0.066	-0.125	0.043*
*Changes in percentage dimensional change statistically significant at P<0.05.							

Table 6.12 Summary of the results of the Wilcoxon Signed Rank Sum Test.

Impregum material group:

Table 6.12 summarizes the results of the Wilcoxon Signed Rank Sum Test for all three impression materials. As depicted in Table 6.12, there is a difference in the percentage dimensional change (Dd) at zero days (-0.051%) and at three days (-0.005%) in the Impregum impression group of materials. Results of the Wilcoxon Signed Rank Sum test indicate that this difference in percentage dimensional change is statistically significant (*P-Value= 0,041*).

However there is no statistically significant difference in the percentage dimensional change at five days from baseline measurements (measurements at day zero) (*P-*

Value=0.080), as well as at seven days from baseline measurements (*P-Value=0.080*) Appendix IV) for Impregum impressions.

Permadyne-Impregum combination group:

Permadyne-Impregum combination revealed a totally different pattern from that of Impregum on its own. There is a statistically significant difference in percentage dimensional change from day zero to three days (*P-Value=0.001*) and from day zero to day seven (*P-Value=0.043*) (Appendix IV and Table 6.12).

However, the difference in percentage dimensional change at day five (*P-Value=0.223*) is not statistically significant (Appendix IV and Table 6.12).

President material group:

The experimental group President demonstrated the lowest mean percentage dimensional change of -0.011% at day zero. This shows that there is negligible percentage dimensional change for this experimental group at day zero. However, the difference in percentage dimensional change is statistically significant at day three (*P-Value=0.042*) and at day seven (*P-Value=0.043*) (Appendix IV and Table 6.12). In addition, the difference in the dimensional change at day five when compared to baseline is not statistically significant (*P-Value=0.066*) (Appendix IV and Table 6.12).

6.6.3 Analysis of percentage dimension change (Dd) between groups

A non-parametric one way analysis of variance (ANOVA) was used to compare the differences that occurred between the experimental groups. The test used to describe this comparison between the groups is the Kruskal Wallis test (Appendix V and Table 6.13).

The results of the Kruskal Wallis test indicate that there is a statistically significant difference in percentage dimensional change (Dd) (*P-Value=0.024*) between the experimental impression material groups. This is summarized in Table 6.13.

ANOVA					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	0.228	2.000	0.114	5.201	0.024
Within Groups	0.263	12.000	0.022		
Total	0.490	14.000			

Table 6.13 Summary of Kruskal Wallis Test for casts poured at seven days from all the impression material groups.

CHAPTER 7

7 DISCUSSION

7.1 Dimensional stability analysis

7.1.1 Preparation technique

In this study unlike in the previous studies discussed in the literature review, a standardized stainless steel die (similar to that described in ADA specification 19), was used for impression making. Both the single and the dual impression techniques using more than one viscosity of materials were used to simulate the clinical situation. In addition, efforts were made to further simulate the clinical situation by placing the experimental setup of making the impressions in a water bath at 32ºC for 3 minutes before bench curing the impression for a further 7 minutes. Most of the previous studies done (Ohsawa and Jorgensen, 1983; William *et al*, 1984; Fingers, 1988; Kanehira *et al*, 2006) used a single stage impression technique using a single material consistency and did not use a warm water bath to simulate the wet oral environment.

7.1.2 Effect of time

In our findings there was no statistically significant difference from baseline measurements for the Impregum impression material group at the end of the experimental period with a mean percentage dimensional change of +0.096 (*P Value= 0.08*) (Table 6.12). However, there were statistically significant differences in the Permadyne-Impregum combination group with a mean percentage dimensional change of +0.163% *(P Value=0.043)* and President with a mean percentage dimensional change of -0.125% *(P Value=0.043*). The results for the President material group was in line with the findings of Chen *et al* (2004) that revealed storage time effect on addition-cured silicones. However, none of the materials showed a change in dimension greater than 1% and this implied that all the materials tested in this study were clinically acceptable according to ADA specification number 19. Inconsistent dimensional changes have been reported for the addition-cured silicones but these studies were conducted by measuring linear changes in freely moving impression materials which was not bound by a tray (Eames *et al*, 1979). In this study the impression material was limited by an adhesive-coated custom made special tray like the one by Marcinak and Draughn (1982).

The differences in the results of previous studies could be attributed to the different methodologies employed. The addition-cured silicone materials may also shrink due to continuing polymerization (Anusavice, 2003). The difference in the maximum dimensional percentage change between the above studies and this study could have been contributed to by the fact that the impressions in this study unlike in the study by Marcinak and Draughn (1982) were subjected to immersion disinfection for 10 minutes, the experimental setup was also immersed in a water bath for three minutes and the measuring instrument used in their study was more accurate to 0.0001mm unlike our instrument which was accurate to only 0.01mm. The greatest change at any given time for their study was -0.3% while for this study the greatest change at any given time was -0.125% for addition-cured silicone and -0.315% for polyethers

In this study Impregum and President had the least change in dimensional stability up to the fifth day after which there was an increase in percentage dimensional change on the seventh day (Figure 6.6). The difference between this study and that of Johnson and Craig (1985) could be explained by the fact that their experimental period was short. All their measurements were taken within 24 hours. Furthermore, the experimental setup was left to stand on the laboratory bench at room temperature and was not subjected to the 32ºC water bath as recommended by ADA specification number 19 (1999). No disinfection of the impressions was done to simulate the clinical situation.

Figures 6.5a, 6.5b, and 6.5c depict the pattern of percentage dimensional change for each impression material respectively over time. Figure 6.6 depicts a line graph representing mean percentage dimensional change per material group with time.

Percentage dimensional changes at day zero pour

At immediate pour, all experimental impression materials exhibited a mean percentage dimensional change (Dd) which was not clinically perceptible (Threshold Dd $\leq$ -0.5%) from baseline, ranging from -0.315% to -0.011% (Table 6.1 and 6.5, Figure 6.1, 6.5a and Figure 6.6).

Permadyne-Impregum combination group had the greatest percentage dimensional change with a mean percentage dimensional change of -0.315%. The Permadyne-Impregum combination group was the least stable material group with the greatest

percentage dimensional change value (Dd = -0.040%) (Table 6.1 and Figure 6.1) and the widest spread of the other values around the mean. The difference between the greatest percentage dimensional change (Dd = -0.040%) and the next highest reading (Dd = -0.011%) was a value of 0.029. This implies that percentage dimensional change between these two specimens within the same group at day zero could be clinically perceptible. This can be attributed to the fact that the polyethers undergo leaching of the water soluble plasticizer and delayed polymerization reaction process leading to the contraction or shrinkage observed in this study (Robert and Craig, 1997; Anusavice, 2003). However, this value was in accordance with the summary provided by the ADA specification number 19 that recommends a maximum percentage dimensional change to be between +0.1% and -0.1% for polyethers generally after twenty four hours (Table 2.2).

President, an addition-cured silicone impression material, exhibited the least change at immediate pour with a mean percentage dimensional change of -0.011%. It is evident that the most stable material group at immediate pour was President despite having an outlier at the 11th reading which corresponded to the minimum value computed at day zero (Dd of -0.040%). This outlier could have resulted from external factors such as improper adjustment of the traveling microscope for that particular specimen. Another reason could be a variation in handling of the material during impression taking. The general stability of this material could be attributed to the fact that as a group, vinyl polysiloxane impression materials' curing mechanism is based on a platinum catalyzed hydrosilation reaction of vinyl groups with no byproduct formation. In addition, vinylpolysiloxane impressions are basically hydrophobic and do not absorb appreciable amounts of water during storage, even when exposed to high ambient humidity (Ohsawa and Jorgensen, 1983; Williams *et al*, 1984; Johnson and Craig 1986; Anusavice, 2003; Chen *et al,* 2004). The next relatively stable material group is the Impregum group which had a mean percentage dimensional change of -0.051% with all the rest of its values narrowly spread around the mean.

From the above results it would be prudent to use President and Impregum impression materials if immediate pour of impression is indicated in a clinical setup. It is evident that based on the results of this study the variation in the Permadyne-Impregum group with a range of values of 0.370% would make the use of the Permadyne-Impregum combination

group problematic as it could lead to lead to less accurate casts and final prosthesis made from such a cast (Table 6.1).

Percentage dimensional changes at three days pour

Minimum change in dimensional stability occurred at three days pour (Table 6.2 and Figures 6.2 and 6.6). The percentage dimensional change ranged from as low as -0.005% (Impregum) to a high of -0.067% (President). These values were not clinically perceptible as they were all below the recommended maximum value of -0.5%. At three days President impression material showed the highest mean percentage dimensional change of -0.067% followed by the Permadyne-Impregum combination with a mean percentage dimensional change of -0.045%. Impregum exhibited the least percentage dimensional change with a mean of -0.005% and a standard deviation (SD = 0.033) with the range for percentage dimensional change values varying from 0.000% to -0.040%. This means that at three days Impregum would produce the best stone die dimensions followed by Permadyne-Impregum combination and thereafter President.

It is evident from Figure 6.2 and Figure 6.6 that Impregum impression material exhibited the least percentage dimensional change even smaller than that at day zero with the mean percentage dimensional change of -0.005%. This was also the lowest dimensional change value across the experimental period. Thus the results suggest that Impregum was the most predictable material when compared to the other experimental material groups at three days pour (Table 6.2 and Figure 6.2). Based on this result, it may be prudent to cast Impregum impressions after three days rather than immediately.

Percentage dimension change at five days pour

Minimal change in dimensional stability (Dd) occurred at day five with Impregum recording the least change in dimensional stability (Mean Dd = -0.011%) from the previous reading at day three (Mean Dd = -0.005%) with a narrow spread around the mean for the rest of it values. Permadyne-Impregum combination had the highest change (Mean Dd = -0.107%) for this experimental group with a great variation around the mean (SD = 0.275). This implies that if an impression can only be poured at five days it would not be advisable to use Permadyne-Impregum combination as it would give inaccurate casts as a result of its instability.

President computed a mean percentage dimensional change value of -0.032% which was an improvement on its value at three days with a standard deviation comparable to that of Impregum (SD = 0.037). All the computed readings for mean percentage dimensional changes were clinically insignificant since they were all below the threshold, -0.5% level (Table 6.3 and Figure 6.6). This means that the impressions made from all the three material combinations could be stored up to five days without much clinically perceptible change. However, Impregum stands out as the most accurate impression materials at five days storage followed by President and thereafter, the Permadyne-Impregum combination.

Percentage dimensional changes at seven days pour

An increase was noticed for all the experimental groups in mean percentage dimensional change from day five to day seven (Figure 6.6).The percentage dimensional change ranged from -0.125% to +0.163%. The mean percentage dimensional change for the Permadyne-Impregum combination (Mean Dd = +0.163%) was regarded as clinically significant as it was above the threshold Mean Dd of +0.1%.

Comparison from baseline indicates that the percentage dimensional change was the highest for Impregum throughout the experimental period with a mean percentage dimensional change of +0.096% and standard deviation of 0.170. President had its highest reading with a mean percentage dimensional change reading of -0.240% and a standard deviation of 0.037. This shows that it had the least variability compared to the other material groups (Table 6.4 and Figure 6.6).

The data from Table 6.5 is depicted graphically in Figure 6.5a, 6.5b, and 6,5c, and Figure 6.6. As evident from Table 6.5, Figure 6.5a and Figure 6.6, Impregum impression material had the least mean percentage dimensional change at the end of three days with a mean percentage dimensional change of -0.005% to a high of +0.096% at the end of seven days.

The variation from the mean was the least across the experimental material groups with time. The overall percentage dimensional change was acceptable according to the requirements outlined in the ISO standards for elastomeric impression materials.

The Permadyne-Impregum combination exhibited the greatest variation from the baseline reading ranging from -0.315% at day zero to a high of +0.163% after seven days. The value for mean percentage dimensional change at seven days was greater than the outlined required negative dimensional change value for polyether impression materials which is -0.5% to -0.1%; this indicates that the mean percentage dimensional change for this group at seven days would result in clinically significant changes in the casts if poured at seven days. These results were in line with the findings of Cynthia *et al* (2003).

The mean percentage dimensional change for President impression material shows the second least variation around the master model mean percentage dimensional change as compared to Impregum up to five days of delay in pouring. However, it is evident that it also maintains a negative percentage dimensional change throughout the experimental period with a mean percentage dimensional change ranging from -0.011% at day zero to -0.125% at day seven.

Degree of percentage dimensional change

The greatest dimensional change was evident between day five and day seven (table 6.6) ranging from -0.083% to +0.270%. The dimensional change is significant for the Permadyne and Impregum group of impression materials as the change in percentage dimensional change is greater than the maximum positive change of +0.1% recommended by the ADA specification 19. Improvement in dimensional change is evident between day three and day five with a change in percentage dimensional change ranging from -0.006% for Impregum, with a deterioration for the Permadyne-Impregum combination material (Dd = +0.035%). This implies that the Impregum impression materials are not as affected by external environmental factors such as humidity, disinfection procedure, and temperature affecting the dimensional change between day three and day five implying that delaying the pour of the Impregum impressions for up to five days would give us more accurate casts and hence prostheses with accurate fit for a better clinical outcome. However, this would not apply to the Permadyne-Impregum combination of impression materials.

Differences in percentage dimensional change

The data from Table 6.6 and Figure 6.7 represents the differences in the mean percentage dimensional change that occurred from day zero to day three, day three to day five, and finally from day five to day seven. Although all impressions were randomly assigned to each experimental group, there was a chance that some groups had a higher number of impressions that had not completed their setting reaction. It is evident from Table 6.6 and Figure 6.7 that marked percentage dimensional change occurred between day zero and day three ranging from -0.056% for President to +0.270% for the Permadyne-Impregum combination group. This would have been clinically significant as the range of mean percentage dimensional change is -0.5% to + 0.1% (ADA specification number 19: 1999).

The greatest dimensional change was evident between day five and day seven ranging from -0.083% for President to +0.270% for Permadyne-Impregum combination group. The dimensional change would have been clinically perceptible for Permadyne-Impregum combination group of impression materials as the change in mean percentage dimensional change is greater than the maximum positive change of +0.1%.

There appears to be a decrease in percentage dimensional change between day zero and day three as well as day three to day five for Impregum and President before a marked increase in mean percentage dimensional change from day five to day seven. This small variation around the mean and baseline measurements for these two materials can be attributed to the materials property of continued polymerization leading to contraction of the impressions made from these materials (Robert and Craig, 1997; Anusavice, 2003).

Clinically it would be possible to store impressions made from president and Impregum for a maximum of five days before pouring and still get accurate casts and precise fit of prostheses made from these casts. The findings of this study was in line with the findings of Cynthia *et al,* (2003) and Kanehiraa *et al,* (2005) who in their study found that addition-cured silicones may be stored for at least up to five days before die pouring without clinically significant dimensional change. They also found that impressions taken with the newer polyethers like Permadyne-Impregum Penta should preferably be poured within less than 24 hours after impression taking in order to avoid the compromising

effects of continuous evaporation of volatile substances from the cured elastomer. However, the results from this study on Permadyne-Impregum combination was not in line with their findings and found it was safer to pour this group of material at around three days but before five days storage as depicted by the results in Figure 6.6 and 6.5b; as the impression recovered to within its original dimension at about 3 days.

The increase in mean percentage dimensional change at day zero storage for Permadyne-Impregum combination material group indicates continued curing process (contraction) (Anusavice, 2003; Cynthia *et al*, 2003). Presumably, the differences between the mean percentage dimensional change values recorded at day zero and day seven is due to volatilization of water from the cured elastomer and later on an unknown contribution of possible water absorption during storage leading to positive mean percentage dimensional change values (expansion) at the end of day seven (Anusavice, 2003; Cynthia *et al*, 2003).

The conventional Polyether Impregum releases volatile substances too but to a lesser degree and this warrants acceptable dimensional accuracy only when stored at ambient relative humidity not exceeding 50% (Cynthia *et al*, 2003; Anusavice, 2003). The smell of even well cured Impregum may be an indicator for this assumption. Thus, the diameter increases found with delay in pour after impression storage at room temperature and relative humidity are supposedly related to evaporation of volatile compounds with time (Cynthia *et al,* 2003). This dimensional deviation might also be due to the combined effect of release of volatile substances from and water absorption in the cured elastomer. The highly hydrophilic Impregum polyether elastomer absorbs appreciable amounts of water from the surrounding atmosphere with time and this explains its change in mean percentage dimension from a negative value (Contraction) to a positive value (Expansion) at day seven (Finger, 1988; Craig and Robert, 1997; Cynthia *et al,* 2003; Anusavice, 2003).

7.1.3 Effect of impression material

Table 6.12 summarizes the results of the Wilcoxon Signed Rank Sum test. Despite the fact that the President impression material does not have polymerization by-products and is not affected by the relative humidity (Craig and Robert, 1997; Cynthia *et al*, 2003;

Anusavice, 2003) that might contribute to minimal dimensional change of impressions taken in it, it displayed a considerable degree of percentage dimensional change with a mean of -0.125% at the end of seven days that was statistically significant (*P Value=0.043*).

The degree of percentage dimensional change observed by President impression material was slightly greater than that for Impregum (Mean Dd = +0.096%) but smaller than that for Permadyne-Impregum combination (Mean Dd = +0.163%) after seven days. Permadyne-Impregum combination experienced the highest percentage dimensional change after seven days (Mean Dd = +0.163) from baseline which is statistically significant (*P Value= 0.043*) and is also clinically significant (Table 6.12). This is similar to the findings of Cynthia *et al* (2003), Chen *et al* (2004) and Kanehiraa *et al* (2005).

This can be explained by the different material properties. Permadyne cures via acid catalyzed cross-linking of the end groups of a silane-terminated polyether compound by a hydrolytic condensation reaction to release by-products such as volatile low molecular alcohols during the condensation reaction; and impressions taken with this polyether type will undergo dimensional changes during storage (Anusavice, 2003; Kanehiraa *et al*, 2005).

As depicted in Table 6.12, Impregum had a percentage dimensional change from zero days (Mean Dd = -0.051%) to three days (Mean Dd = - 0.005%) in this experimental group of materials. Results of the Wilcoxon Signed Rank Sum test indicate that this change in percentage dimension change is statistically significant (*P-Value=0.041*). However, Impregum showed the least percentage dimensional change (Mean Dd = +0.096%) with no statistical significant difference at five days (*P-Value=0.080*), as well as at seven days (*P-Value=0.080*).

The results of Kruskal Wallis test indicate that there is a statistically significant difference in percentage dimensional change (Dd) (*P-Value=0.024*) between the three impression material groups. The results obtained from this study support the null hypothesis that there is no significant difference in dimensional change between the polyethers and addition-cured silicones if the impression is to be poured after one week based on the analysis in Table 6.13.

7.2 Surface detail score analysis

In addition to the measurements of dimensional accuracy, this study also examined surface detail reproduction of the elastomeric impression materials. Tables 6.7, 6.8, and 6.9, and Figure 6.8, 6.9 and 6.10 depicts the surface detail scores for the various materials. Table 6.9 gives the overall surface detail score for all the experimental groups. Surface detail reproduction was assessed by scoring standardized photographs of the impression surfaces at 10 times magnification. The scoring system used graded the photographs from grade 1 to 4 with grade 1 being the best score and grade 4 the worst. Additionally, grade 1 and 2 are considered clinically acceptable and grade 3 and 4 are considered clinically unacceptable

7.2.1. Effect of time and materials

Table 6.10 and Figure 6.11 show the overall surface detail score per study group. The total for the surface detail score 1 was 24 out of 60 experimental samples (40%). The surface detail score of 2 was 36 out of a total of 60 experimental samples (60%). Impressions poured at zero days and three days had the highest score for surface detail score of 1 with a value of 7 followed by impressions poured at five days and seven days with a value of 5 respectively. A Chi-Square statistical test was done to investigate whether the three impression materials groups gave the same results as pertains to surface detail reproduction (*P- Value =0.00001*) (Table 6.11 and Figure 6.12). This indicates that the overall surface detail score statistical test result was highly significant implying that there was a variation in how the three experimental materials group reproduces surfaces.

The statistical results for this study on surface detail reproduction indicate that time had a significant effect on surface detail for all the materials (*P Value=0.000*). Despite the fact that impressions made from all the three material groups were 100% satisfactory when examined without assisted vision reproducing at least 2 of 3 lines continuously, the value of scores for impregum at five days and seven days was 100% score 2, implying that the surface deteriorated at five and seven days and therefore there should not be a long delay before pouring the impression. This means that is advisable to pour the impressions within the first three days in order to avoid surface deterioration of the impressions.

Figure 6.11 depicts the proportion of the various scores with score of 1 showing a high of 67% for Permadyne and Impregum followed by 25% for Impregum and 8% for President impression materials. Although the additive surfactants have improved the polymerized addition-cured silicones material's wettability with dental gypsum materials (Anusavice, 2003), it appears that this impression material still cannot accurately reproduce detail in the presence of moisture. The findings in this aspect of the study are in line with that of Cynthia *et al*, (2003).

The results in this study could not be compared with that of Pant *et al*, (2008) since the difference in storage time in the two studies was big. However, preliminary surface detail reproduction results from the pilot study revealed that in some impressions, there were areas of pits, voids, and roughness not associated with the 3 horizontal lines used for the ADA detail reproduction evaluation. If such pits or voids were located in the preparation margin, the impression would be clinically unacceptable. The composite column chart (Figure 6.12) and Table 6.11 shows that all the three impression materials tested were satisfactory with respect to surface detail reproduction when evaluated according to a criteria similar to ADA specification No.19 (1999).

However, the Chi square statistical test showed a statistically significant difference (*P Value= 0.0000*) in surface detail scores between all the three impression material groups (Table 6.11). Permadyne-Impregum combination material would be the best material combination to use where a detailed impression is required. In addition to the excellent surface detail reproduction score for this material combination group, our findings on dimensional stability with time indicate that it would be best to use Permadyne-Impregum combination material on the third day of pour as it combines both its best qualities in dimensional stability and surface detail score (Tables, 6.2, 6.5, 6.8, 6.10, 6.11 and Figures 6.2, 6.5b, 6.6, 6.9, 6.11 and 6.12).

CHAPTER 8

8 LIMITATIONS OF THE STUDY

In vitro studies are dependent on various factors that can affect the outcome of the study. Thus controlling all the external factors that might play a role in the end result can be difficult. The primary limitation in this study was the difficulty to control the absolute environmental factors such as the humidity and room temperature in the laboratory over the experimental period. Although random sampling was carried out, the difference in the time taken to take all the sixty impressions before the sampling was another factor that might have affected the results. In addition the Impregum impression material for the Impregum material group was hand-mixed whereas the rest of the materials were extruded from automatic dispensers.

The inability to reproduce an exact clinical situation is another limitation of this study. The oral environmental temperature of 32 ºC was mimicked by allowing the impressions to stand in a waterbath at the said temperature for three minutes and thereafter immersion disinfection for 10 minutes after setting. However, water in a water bath instead of saliva was used as the source of moisture. The properties of saliva are quite different from those of water, and these differences could potentially have affected the behavior of the impression materials (Cynthia *et al*, 2003; Anusavice, 2003). In addition, placing the experimental setup in a water bath was meant to simulate the wet oral environment in a clinical situation in contrast to oral tissues where there is water at the surface, as well as water within the bulk of the tissue. Water within the bulk tissue can diffuse to the surface during the recording of an impression. It would be very difficult to duplicate this type of moisture contamination in the laboratory.

Unlike most of the previous studies in which the experimental die was in three dimensions and could be measured in both horizontal and vertical dimensions, this study did not simulate the clinical protocol of mimicking the clinical situation. Statistically, the greater the sample size the more reliable the results. The sample size for each group in this study was relatively small (n=5).The duration of the study was also relatively short.

In this study the surface detail reproduction impressions were made of a standardized stainless steel die. Although the metal die was a calibrated surface for precise

comparisons, it did not resemble the behavior of the oral tissues. For example, the metal die does not absorb liquids. In addition, the intrinsic surface-free energy of a metal die is much higher than the surface-free energy of the proteinaceous surfaces of prepared teeth and oral soft tissues (Wassell and Abuasi, 1992). This surface energy of the impressed surface affects how well the impression material wets that surface.

These factors could have further limited the outcome of this *in vitro* study. Although all these factors might be considered as limitations to *in vitro* studies, the importance of this type of research in predicting the clinical outcome must not be ignored as it is an indicator of what could happen in the clinical setting.

CHAPTER 9

9 CONCLUSION AND RECOMMENDATIONS

9.1Conclusion

The results of this study support the null hypothesis that there is no statistically significant difference in the dimensional stability of the polyethers and the addition-cured silicones if there is a delay of pour of up to seven days. However, the results do not support the null hypothesis that there are no statistically significant differences between the addition-cured silicones and the polyethers with regard to surface detail reproduction.

In conclusion, the results obtained from the Chi Square test indicates that the difference as regards surface detail of casts poured from the different impression materials is statistically significant (*P Value= 0.000*) with the Permadyne-Impregum combination material group computing the best surface detail score followed by Impregum and thereafter the President material group.

Wilcoxon Rank Sum test indicates that there is a considerable effect of time on dimensional stability. The dimensional stability and surface details do change with time. Overall there was a statistically significant difference in the degree of dimensional stability between the Impregum and the Permadyne-Impregum combination group as well as between Impregum and President material groups at the end of seven days. However, there was no statistically significant difference between the Impregum and President material groups when poured within and up to five days.

Kruskal Wallis (one-way ANOVA) was used to compare the differences that occurred between the experimental groups. The results of the Kruskal Wallis test indicates that there is a statistically significant difference in percentage dimensional change (*P-Value=0.024*) between the experimental impression material groups.

It is evident from this study that the Permadyne-Impregum combination impression material exhibited the overall best surface detail score with time. This means that it would be the best material to use if the delay of pour of material not exceeding 5 days is required and if a high precision impression is required as long as it is poured within the third to fifth day. In addition, the Permadyne-Impregum combination group exhibited its

best of both dimensional stability and surface detail reproduction properties on the third day of pour implying that it would be prudent to pour the impressions on the third day in order to maximize on the best of both material properties.

The President and the Impregum material groups were relatively stable up to the fifth day and therefore they could be used in situations where the impressions have to be poured earlier or later than three days as long as the storage time does not exceed five days.

9.2 Recommendations

On the basis of this study, it is recommended to use Impregum and President Impression materials for taking impressions if a delay of pour of up to one week is required. This is because these two material groups computed mean percentage dimensional change values below the ADA specification number 19 (1999) (Mean Dd = -0.5% and +0.1%) for elastomeric impression materials at the end of the experimental period of seven days. However, the water absorption characteristic of Polyethers must be taken into account when impressions are sent to long distant dental laboratories, particularly when being shipped together with alginate impressions, wrapped in wet towels to curb the adverse effects on dimensional accuracy due to water absorption expansion. An alternative would be for the clinician to pour the impression in a gypsum product as soon as it is recommended by the manufacturer and thereafter freight the cast instead of the impression.

Future research in this field is however required, utilizing a larger sample and integrating all the variables that are known to affect the dimensional stability and accuracy of elastomeric impression materials all in one setting. The variables to be included should include the effect of high and low temperatures, effect of humidity, impression techniques and other handling characteristics. Future research should make an attempt to measure the linear measurements directly on the impressions to see if there are any errors that could be introduced during pouring of the casts and from gypsum products' properties. Further research in this field can help the manufacturers to come up with a more stable and accurate material for use if a delay in pour of the impression is indicated.

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Appendix I

Raw data

0 days (Group I)

Date	Materials	Reading1	Reading2	Reading3	surface detail score
23/05/08	Impregum	25.01	25.00	25.02	2
23/05/09	Impregum	25.02	25.01	25.02	1
23/05/10	Impregum	25.00	25.01	25.02	1
23/05/11	Impregum	25.02	25.02	25.01	1
23/05/12	Impregum	25.02	25.00	25.01	2
23/05/13	Permadyne- Impregum	25.06	25.04	25.06	2
23/05/14	Permadyne-Impregum	25.08	25.10	25.10	1
23/05/15	Permadyne- Impregum	25.08	25.09	25.10	1
23/05/16	Permadyne-Impregum	25.10	25.10	25.08	2
23/05/17	Permadyne- Impregum	25.06	25.07	25.06	2
23/05/18	President Putty/light body	25.01	24.99	25.00	1
23/05/19	President Putty/light body	25.00	25.01	25.00	2
23/05/20	President Putty/light body	25.01	25.00	24.99	2
23/05/21	President Putty/light body	25.00	24.99	25.01	1
23/05/08	President Putty/light body	25.02	25.00	25.01	2

3 days (Group II)

Date	Materials	Reading1	Reading2	Reading3	surface detail score
26/05/09	Impregum	25.02	25.01	25.00	1
26/05/10	Impregum	24.98	25.00	25.00	1
26/05/11	Impregum	24.99	25.00	25.01	2
26/05/12	Impregum	25.01	24.99	24.98	2
26/05/13	Impregum	25.02	25.01	25.00	1
26/05/14	Permadyne-Impregum	25.00	25.00	25.01	1
26/05/15	Permadyne-Impregum	25.03	25.00	25.01	2
26/05/16	Permadyne-Impregum	25.00	25.03	25.01	1
26/05/17	Permadyne-Impregum	25.02	25.00	25.04	1
26/05/18	Permadyne and Impregum	25.01	25.00	25.01	1
26/05/19	President Putty-light body	25.04	25.02	25.03	2
26/05/20	President Putty-light body	25.02	25.00	25.01	2
26/05/21	President Putty-light body	25.00	25.01	25.03	2
26/05/22	President Putty-light body	25.03	25.00	25.02	2
26/05/08	President Putty-light body	25.01	25.02	25.01	2

5 days (Group III)

Date	Materials	Reading1	Reading2	Reading3	surface detail score
28/05/09	Impregum	25.00	25.01	25.00	2
28/05/10	Impregum	25.03	25.01	25.02	2
28/05/11	Impregum	25.01	25.00	24.99	2
28/05/12	Impregum	24.99	24.98	24.99	2
28/05/13	Impregum	25.00	25.01	25.00	2
28/05/14	Permadyne-Impregum	24.98	24.99	25.00	1
28/05/15	Permadyne-Impregum	25.00	24.98	24.99	1
28/05/16	Permadyne-Impregum	25.12	25.10	25.09	1
28/05/17	Permadyne-Impregum	25.11	25.08	25.10	1
28/05/18	Permadyne-Impregum	24.95	24.96	24.95	1
28/05/19	President Putty-light body	25.02	24.99	25.00	2
28/05/20	President Putty-light body	25.01	25.00	25.00	2
28/05/21	President Putty-light body	24.99	25.00	25.01	2
28/05/22	President Putty-light body	25.02	25.04	25.01	2
28/05/23	President Putty-light body	25.00	25.02	25.01	2

7 days (Group IV)

Date	Materials	Reading1	Reading2	Reading3	surface detail score
30/05/08	Impregum	25.00	25.01	25.01	2
30/05/09	Impregum	24.94	24.92	24.92	2
30/05/10	Impregum	24.99	24.98	25.00	2
30/05/11	Impregum	24.92	24.94	24.94	2
30/05/12	Impregum	25.02	25.04	25.01	2
30/05/13	Permadyne-Impregum	24.90	24.93	24.91	1
30/05/14	Permadyne-Impregum	24.96	24.95	24.98	1
30/05/15	Permadyne-Impregum	25.03	25.02	24.98	1
30/05/16	Permadyne-Impregum	24.98	24.99	25.00	1
30/05/17	Permadyne-Impregum	24.92	24.94	24.90	1
30/05/18	President Putty-light body	25.00	25.01	25.01	2
30/05/19	President Putty-light body	25.10	25.00	25.08	2
30/05/20	President Putty-light body	25.06	25.04	25.02	2
30/05/21	President Putty-light body	25.03	25.00	25.04	2
30/05/22	President Putty-light body	25.04	25.02	25.02	2

Appendix II

Calculations of percentage dimensional change

Group I (0 Days)

Study group	Material	Percentage Dimension Change (%)
Group I	Impregum	-0.04
Group I	Impregum	-0.07
Group I	Impregum	-0.04
Group I	Impregum	-0.07
Group I	Impregum	-0.04
Group I	Permadyne-Impregum	-0.21
Group I	Permadyne-Impregum	-0.37
Group I	Permadyne-Impregum	-0.36
Group I	Permadyne-Impregum	-0.37
Group I	Permadyne-Impregum	-0.25
Group I	President Putty - Light body	0.00
Group I	President Putty - Light body	-0.01
Group I	President Putty - Light body	0.00
Group I	President Putty - Light body	0.00
Group I	President Putty - Light body	-0.04

Group II (3 Days)

Study group	Material	Percentage Dimension Change (%).
Group II	Impregum	-0.04
Group II	Impregum	0.03
Group II	Impregum	0.00
Group II	Impregum	0.03
Group II	Impregum	-0.04
Group II	Permadyne-Impregum	-0.01
Group II	Permadyne-Impregum	-0.05
Group II	Permadyne-Impregum	-0.05
Group II	Permadyne-Impregum	-0.08
Group II	Permadyne-Impregum	-0.03
Group II	President Putty - Light body	-0.12
Group II	President Putty - Light body	-0.04
Group II	President Putty - Light body	-0.05
Group II	President Putty - Light body	-0.07
Group II	President Putty - Light body	-0.06

Group III (5 Days)

Study group	Material	Percentage Dimension change (%)
Group III	Impregum	-0.01
Group III	Impregum	-0.08
Group III	Impregum	0.00
Group III	Impregum	0.05
Group III	Impregum	-0.01
Group III	Permadyne-Impregum	0.04
Group III	Permadyne-Impregum	0.04
Group III	Permadyne –Impregum	-0.41
Group III	Permadyne-Impregum	-0.39
Group III	Permadyne –Impregum	0.19
Group III	President Putty-Light body	-0.01
Group III	President Putty-Light body	-0.01
Group III	President Putty-Light body	0.00
Group III	President Putty-Light body	-0.09
Group III	President Putty-Light body	-0.04

Group IV (7 Days)

Study group	Material	Percentage Dimension change
Group IV	Impregum	-0.03
Group IV	Impregum	0.29
Group IV	Impregum	0.04
Group IV	Impregum	0.43
Group IV	Impregum	-0.09
Group IV	Permadyne-Impregum	0.35
Group IV	Permadyne-Impregum	0.15
Group IV	Permadyne-Impregum	-0.04
Group IV	Permadyne-Impregum	0.08
Group IV	Permadyne-Impregum	0.32
Group IV	President Putty-Light body	-0.03
Group IV	President Putty-Light body	-0.24
Group IV	President Putty-Light body	-0.16
Group IV	President Putty-Light body	-0.09
Group IV	President Putty-Light body	-0.11

Appendix III

CHI-Squared statistical test for surface detail score

Material	**Permadyne- Impregum combination**				
Study groups	0 days	3 days	5 days	7 days	Total
Surface detail score 1	2	4	5	5	16
Surface detail score 2	3	1	0	0	4
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20
Test Statistic CHI-Squared = 7.5 ***P-Value = 0.0576***					

Material	**President**				
Study groups	0 days	3 days	5 days	7 days	Total
Surface detail score 1	2	0	0	0	2
Surface detail score 2	3	5	5	5	18
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20
Test Statistic CHI-Squared = 6.6667 ***P-Value = 0.0833***					

Material	**Impregum**				
Study groups	0 days	3 days	5 days	7 days	Total
surface detail score 1	3	3	0	0	6
surface detail score 2	2	2	5	5	14
Surface detail score 3	0	0	0	0	0
Surface detail score 4	0	0	0	0	0
Total	5	5	5	5	20
Test Statistic CHI-Squared = 8.5714 ***P-Value = 0.0356***					

Appendix IV

Wilcoxon Signed Rank Sum Test

Paired data analysis of differences between change day 0 and day 3

Material	Day 0	Day 3	Wilcoxon Signed Rank Sum Test
Impregum	-0.067	-0.040	
Impregum	-0.067	-0.040	Number of Nonzero Differences = 5
Impregum	-0.040	0.000	
Impregum	-0.040	0.027	
Impregum	-0.040	0.027	Large sample Approximation
			Test Statistics Z = -2.041
minimum	-0.067	-0.040	**P-Value = 0.041**
Q1ts	-0.040	0.000	
Mean	-0.051	-0.005	
Q3rd	-0.067	-0.040	
maximum	-0.040	0.027	
Permadyne-Impregum	-0.373	-0.080	Number of Nonzero Differences = 5
Permadyne- Impregum	-0.373	-0.053	
Permadyne-Impregum	-0.360	-0.053	
Permadyne-Impregum	-0.253	-0.027	Large sample Approximation
Permadyne-Impregum	-0.213	-0.013	Test Statistics Z = -2.023
			P-Value = 0.001
minimum	-0.373	-0.080	
Q1ts	-0.360	-0.053	
Mean	-0.315	-0.045	
Q3rd	-0.373	-0.066	
maximum	-0.213	-0.013	
President	-0.040	-0.120	
President	-0.013	-0.067	Number of Nonzero Differences = 5
President	0.000	-0.053	
President	0.000	-0.053	
President	0.000	-0.040	Large sample Approximation
			Test Statistics Z = -2.032
minimum	-0.040	-0.040	**P-Value = 0.042**
Q1ts	0.000	-0.053	
Mean	0.011	-0.067	
Q3rd	-0.027	-0.053	
maximum	0.000	-0.120	

Paired data analysis of differences between change day 0 and day 5

Wilcoxon Signed Rank Sum Test			
Material	**Day 0**	**Day 5**	**Wilcoxon Signed Rank Sum Test**
Impregum	-0.067	-0.080	
Impregum	-0.067	-0.013	Number of Nonzero Differences = 5
Impregum	-0.040	-0.013	
Impregum	-0.040	0.000	
Impregum	-0.040	0.053	Large sample Approximation
			Test Statistics Z = -1.753
minimum	-0.067	-0.080	P-Value = 0.080
Q1ts	-0.040	-0.013	
Mean	-0.051	0.011	
Q3rd	-0.067	-0.047	
maximum	-0.04	0.053	
Permadyne-Impregum	-0.373	-0.413	
Permadyne-Impregum	-0.373	-0.387	Number of Nonzero Differences = 5
Permadyne-Impregum	-0.360	0.040	
Permadyne-Impregum	-0.253	0.040	
Permadyne-Impregum	-0.213	0.187	Large sample Approximation
			Test Statistics Z = -1.219
minimum	-0.373	-0.413	P-Value = 0.222
Q1ts	-0.360	0.040	
Mean	-0.315	-0.107	
Q3rd	-0.373	-0.400	
maximum	-0.213	0.187	
President	-0.040	-0.093	
President	-0.013	-0.040	Number of Nonzero Differences = 5
President	0.000	-0.013	
President	0.000	-0.013	
President	0.000	0.000	Large sample Approximation
			Test Statistics Z = -1.841
minimum	-0.040	-0.093	P-Value = 0.066
Q1ts	0.000	-0.013	
Mean	0.011	-0.032	
Q3rd	-0.027	-0.067	
maximum	0.000	0.000	

Paired data analysis of differences between day 0 and day 7

Material	Day 0	Day 7	Wilcoxon Signed Rank Sum Test
Impregum	-0.067	-0.093	Number of Nonzero Differences = 5
Impregum	-0.067	-0.027	
Impregum	-0.040	0.040	Large sample Approximation
Impregum	-0.040	0.267	Test Statistics Z = -1.753
Impregum	-0.040	0.293	P-Value = 0.080
minimum	-0.067	-0.093	
Q1ts	-0.040	0.040	
Mean	-0.051	0.096	
Q3rd	-0.067	-0.060	
maximum	-0.040	0.293	
Permadyne- Impregum	-0.373	-0.040	Number of Nonzero Differences = 5
Permadyne-Impregum	-0.373	0.040	
Permadyne-Impregum	-0.360	0.147	
Permadyne-Impregum	-0.253	0.320	Large sample Approximation
Permadyne-Impregum	-0.213	0.347	Test Statistics Z = -2.023
			P-Value = 0.043
minimum	-0.373	-0.040	
Q1ts	-0.360	0.147	
Mean	-0.315	0.163	
Q3rd	-0.373	0.000	
maximum	-0.213	0.347	
President	-0.040	-0.240	Number of Nonzero Differences = 5
President	-0.013	-0.160	
President	0.000	-0.107	
President	0.000	-0.093	Large sample Approximation
President	0.000	-0.027	Test Statistics Z = -2.023
			P-Value = 0.043
minimum	-0.040	-0.240	
Q1ts	0.000	-0.107	
Mean	-0.011	-0.125	
Q3rd	-0.027	-0.200	
maximum	0.000	-0.027	

Appendix V

Kruskal Wallis Test

(Non-parametric one-way ANOVA)

Comparing percentage dimensional change at seven days between material groups

Impression material	Impregum	Permadyne-Impregum	President		
1	-0.090	-0.040	-0.240		
2	-0.030	0.040	-0.160		
3	0.040	0.150	-0.110		
4	0.270	0.320	-0.090		
5	0.290	0.350	-0.030		
Minimum	-0.093	-0.040	-0.240		
Q1st	-0.121	-0.048	-0.059		
Mean	0.096	0.163	-0.125		
Q3rd	0.078	0.373	0.148		
Maximum	0.293	0.347	0.347		
ANOVA ***Results for Seven days storage group.***					
	Sum of Squares	***df***	***Mean Square***	***F***	***Sig.***
Between Groups	0.228	2.000	0.114	5.201	0.024
Within Groups	0.263	12.000	0.022		
Total	0.490	14.000			