**The effect of dehydration on the dimensional stability of acrylic partial denture bases**

Submitted in fulfilment of the requirements for the award of the degree of Master of Health Sciences: Dental Technology

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## Dedication

This dissertation is dedicated to my parents for giving me love, support and encouragement in my life and for moulding me into what I have achieved.

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## Abstract

Removable acrylic dentures are often used to restore both function and aesthetics of edentulous patients. This treatment option is commonly advocated because acrylic partial dentures are simple to manufacture, finish and adjust during clinical fitting. The main drawback of an acrylic denture, however, is that it is porous in nature. Consequently, water, saliva or any other oral fluids can be absorbed during intraoral use and storage. This severely compromises the fit, comfort and stability of the denture base in the patient's mouth. Acrylic dentures that are not stored in water during periods of disuse can also deform and become brittle. Deformation of acrylic denture base stored post-manufacture, and prior to intraoral fitting, may also occur in the absence of hydration. The atmosphere in which the acrylic partial denture is stored may contribute to the level of hydration, which can further cause dimensional instability of the denture bases. The focus of this study was to investigate the extent of dimensional instability of acrylic partial denture bases by temperature and humidity.

A positivist paradigm was followed and an experimental research design within a quantitative framework was used. There were three sample groups namely; the hydrated 9-hour cure *(Control);* dehydrated 9-hour cure *(Group 1);* and dehydrated 1½-hour cure *(Group 2)*. Each sample group had ten specimens (n=30). In determining the extent of the dimensional instability of the acrylic partial denture bases by temperature and humidity, the acrylic partial denture bases for the dehydrated 9-hour cure and dehydrated 1½-hour cure were stored in a custom-made incubator for 28 days with the temperature and humidity levels regulated at 21ºC and 40%, respectively. The 9-hour cured acrylic partial denture bases were stored in a water bath at 37ºC for 28 days. The dimensional deformation of the acrylic partial denture bases were measured immediately after fabrication (day 1) and subsequently on days 2, 7, 14, 21 and 28.

The silicone wafer method was used to measure the degree of deformation of the acrylic partial denture bases. The process entailed pouring a silicone (Mold Max® 30) mixture onto the gypsum models and fitting the acrylic partial denture bases using finger pressure. Following the setting of the silicone, the acrylic

partial denture bases were carefully removed from the gypsum model. The thickness of the silicone layer was measured using a micrometer (Mitutoyo® S293, America Corporation, Illinois, United States of America) at four reference areas. These reference areas were the incisive papilla; the area of the first molars (16 and 26); and the deepest part of the midline posteriorly. Validity was achieved following the South African National Standard for Denture base polymers (SANS 861). Reliability was maintained using a temperature control unit and a calibrated thermo-hygrometer. The Kruskal-Wallis non-parametric test and Dunn's Multiple Comparison test (SPSS® Version 24) were used to analyse the degree of deformation in the areas mentioned above ($p$=0.05). The slope test was further used to compare the deformation trends of each sample group (Graph Pad Prism® Version 5).

The Kruskal-Wallis test and Dunn's Multiple Comparison test revealed no significant differences for the three groups ($p$>0.05). The slope test revealed no significant differences in the incisal area ($p$>0.42). There were significant differences in the posterior area of the acrylic denture bases, particularly in the first molar (26) area ($p$<0.04). Overall, the prominent features of this study showed that the dehydrated 1½-hour cured acrylic partial denture bases had the highest deformation. The hydrated 9-hour cured acrylic partial denture bases, by contrast, had the lowest deformation. Notably, this study conclusively showed that curing acrylic partial dentures for nine hours increases the dimensional fit, which is further enhanced if kept hydrated on storage. Future research to consider the dry-stored parameters of acrylic partial denture bases is recommended, as this could provide useful guidelines to both clinicians and patients in reducing deformation on storage, thereby improving denture care practices.

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# Acronyms and Terminology

Within this dissertation various acronyms and terminologies are used as outlined below.

**Acronym**

| | |
|---|---|
| **APD** | Acrylic Partial Denture |
| **DUT** | Durban University of Technology |
| **PMMA** | Poly Methyl Methacrylate |
| **RH** | Relative Humidity |
| **RPD** | Removable Partial Denture |
| **UoT** | University of Technology |

**Terminology**

1. Abutment: An abutment is a tooth that acts as an anchor on which the clasps are placed to support and stabilise the removable partial denture (Prasad *et al.* 2013).

2. Complete denture: A complete denture is defined as a dental prosthesis which replaces the entire dentition and associated structures of an edentulous mouth. A complete denture is supported by bone and is covered by soft tissue; it restores the 'lost' facial contours while enabling mastication and improving patient speech (Sowter 1986; Nallaswamy 2007).

3. Curing/Polymerisation Cycle: The heating process used to control polymerisation. Poly methyl methacrylate denture bases should be processed at a constant temperature in a curing bath at 74ºC for nine hours (Anusavice, Shen and Rawls 2013).

4. Denture base: The denture base forms the foundation of the denture and it helps to distribute and transmit all the forces acting on the denture teeth to

the supporting tissue. Artificial teeth are attached to the denture base, which rests on the oral mucosa (Babu, Manjunath and Vajawat 2016).

5. Denture Flange: The denture flange is the vertical extension from the body of the denture to the vestibules of the oral cavity. The denture flange together with its base provide horizontal, anteroposterior and lateral stability of the denture (Chen *et al*. 2014; Abdulwaheed 2016).

6. Monomer: A chemical compound capable of reacting to form a polymer (Anusavice, Shen and Rawls 2013).

7. Polymer: A Chemical compound consisting of high organic molecules formed by the union of many repeating low monomer units (Anusavice, Shen and Rawls 2013).

8. Removable partial denture: Restores the dentition of partially edentulous patients by replacing one or more teeth but not all the teeth in the oral cavity (Sowter 1986; Nallaswamy 2007).

# Chapter 1- Introduction

## 1.1 Background

The loss of all dentition is a life-changing event that brings functional and aesthetic challenges. There are several treatment and prosthetic options for patients, depending on a number of considerations. Prosthetic options for complete and partially edentulous patients are fixed, removable and hybrid prostheses. Removable acrylic complete and partial dentures are often selected by patients because of the low cost, acceptable aesthetics and ease of adjusting the prosthesis during final fitting (Finbarr 2010; Carr and Brown 2011).

The term ‘edentulous’ is used when a person has completely lost all their natural teeth. Geminiani (2016) therefore indicates that a treatment option for an edentulous patient is conventional complete dentures. According to Sowter (1986: 3) a removable complete denture is defined as “a dental prosthesis which replaces the entire dentition and associated structures of an edentulous mouth”. A point to be noted is that Sowter’s work is seminal in Dental Technology and to date his work is used in the training of dental technicians at the various South African Universities of Technology (UoTs). Sowter (1986) and Nallaswamy (2007) further note that a complete denture is supported by bone and is covered by soft tissue; it restores the ‘lost’ facial contours while enabling mastication and improving patient speech. Complete dentures should also be correctly fabricated by a dental technician, particularly providing a proper balanced occlusion to enhance the stability of the denture intraorally. Moreover, fixed or removable partial dentures (RPDs) restore the dentition of partially edentulous patients by replacing one or more teeth but not all the teeth in the oral cavity (Sowter 1986 and Nallaswamy 2007).

The primary difference between a complete denture and a RPD is the method by which the prosthesis gains support. In contrast to complete dentures, and as argued by Sowter (1986) and Nallaswamy (2007), RPDs gain support from the bone covered by the mucosa and from the remaining teeth. Generally, and as indicated above, a contributing factor for the patient choosing an acrylic partial denture (APD) instead of metal RPDs is the cost. Other factors outlined by Finbarr (2010) and Carr and Brown (2015) are the ease of fabrication, as well as finishing and adjusting the prosthesis during clinical fitting. A disadvantage pointed out by Paulose (2005), however, is that the denture base acrylic used to fabricate APDs is porous thereby leading to distortion and warpage of the denture base.

Poly Methyl Methacrylate (PMMA), which is commonly referred to as denture base acrylics, is frequently used to fabricate complete dentures and APDs. As elaborated by Meng and Latta (2005: 93), PMMA remains the preferred material for APDs because of its "low cost, relative ease of use and reliance on simple processing equipment". Given the function of a denture base in APDs, high flexural and impact strengths would increase the clinical service life. To achieve the maximum strength properties of PMMA, curing complete dentures for nine hours at 74ºC in a curing bath is advocated. Several authors (Consani *et al.* 2002; Ghassan 2008; Tuna *et al*. 2008; Bhola *et al.* 2010; Anusavice, Shen and Rawls 2013; Ivkovic *et al.* 2013; Rashid, Sheikh and Vohra 2015) have reported that curing at a higher temperature for a longer period of time (9-hours at 74ºC) reduces the leachable residual unreacted (free) monomer. Moreover, Ghassan (2008) and Tuna *et al.* (2008) advised not to use reduced curing cycles at temperatures reaching boiling point, as this can lead to distortion of acrylic complete denture bases. Despite their advice, qualified dental technicians from industry (in a telephone conversation on 15 March 2015 with Mr Y. Boodhun (Dental Technician) and Mr C. Polinski (Dental Technician) use a reduced curing cycle that is 1½ -hours at 45ºC to boiling point in order to save time.

Furthermore, the fabrication of APDs requires several clinical appointments at the dental surgery in conjunction with several dental laboratory procedures (Sowter 1986; Jones and Garcia 2009). Generally the clinical and laboratory processes end at the third clinical appointment, when the patient has the final fitting of the manufactured prosthesis. Challenges of fitting the APD arise prior to, or at this third and final clinical appointment. In some instances a misfit may occur and result in the patient rejecting the prosthesis. A number of factors ranging from impression inadequacies to deformation on storage, amongst other pre- and post-processing challenges, cause misfits of dentures (Rashid, Sheikh and Vohra 2015). Notwithstanding this, Consani, Domitti and Consani (2002) reported that water, saliva and food particles can be absorbed and released by the acrylic denture base during use and storage. Consequently, absorption and emission of oral fluids can produce dimensional changes to the denture base. This compromises the fit, strength, comfort and stability of the denture base intraorally. This study therefore focused on the effect of dry storage of APDs post-manufacture and prior to the final fitting of the prosthesis.

### 1.2 Problem Statement

As noted earlier, the cyclic sorption and omission of fluid results in deformation and crazing of the denture base over time resulting in fatigue stress. Crazing is the formation of surface cracks on the denture base. Over time, crazing can weaken the denture and may result in fatigue stress fracture (Hussain 2004; Seo *et al.* 2006). Dental clinical and laboratory personnel therefore advise patients to store their dentures in water when not in use. Notwithstanding this, several authors (Barclay and Walmsley 1998; Mohamed, Al-Jadi and Ajaal 2008; Ghassan 2008) have reported that prolonged exposure periods to the atmosphere cause acrylic dentures to deform and become very brittle. They therefore advised that constant moisture levels be maintained to reduce the occurrence of the hydration-dehydration cyclic stresses within acrylic denture bases.

### 1.3 Rationale for the Study

Consani *et al*. (2011) reported on the distortion of complete denture bases, particularly during storage at room temperature over a 24-week period. They revealed that denture bases distorted significantly when stored at room temperature rather than in water. In support of their findings, Kasina *et al.* (2013) concluded that positive correlations exist between the polymerisation cycles and degree of hydration and dehydration during storage, particularly in terms of influencing denture deformation. The aforementioned authors specifically referred to complete denture deformation, however, with no reference to APD bases**.** Moreover, the shape of a complete denture base (Figure 1-1) is different from an APD (Figure 1-2). Deformation of APD bases may therefore manifest differently.

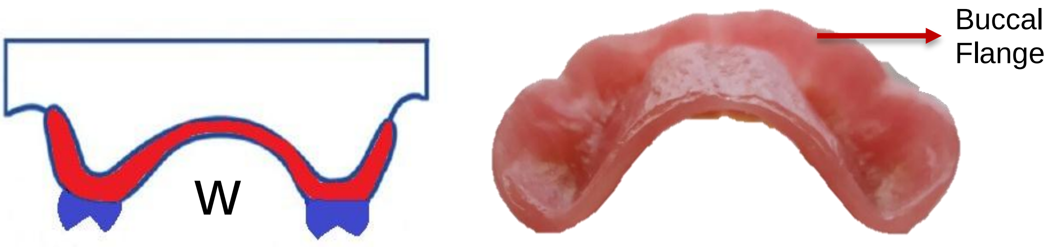


**Figure 1-1:** The **'w'** shape of a maxillary complete denture base when viewed posteriorly

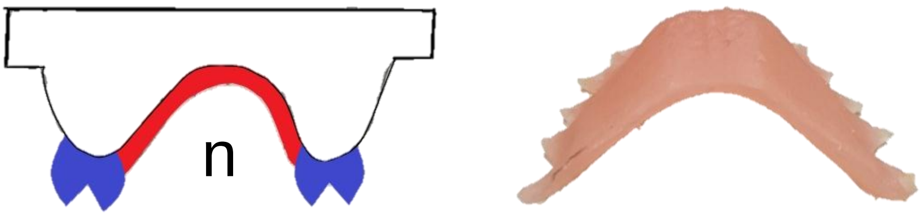


**Figure 1-2:** The **'n'** shape of a maxillary APD when viewed posteriorly

Recently Lim and Lee (2016) observed significant linear bilateral posterior buccal flange deformation of complete dentures during dry-storage. In view of Figures 1-1 and 1-2, this is more likely to be different in APDs because of the absence of a buccal flange. Notwithstanding this and despite several studies reporting on the effect of hydration and dehydration of complete acrylic denture bases with varying results (Joshi and Sanghvi 1994; Al Nori, Hussain and Rejab 2006; Meloto *et al.* 2006; Consani *et al.* 2011), there is limited research on the dehydration and deformation of APDs post-manufacture. It was therefore anticipated that analysing deformation of 'n'-shape maxillary APDs could provide dental practitioners with guidelines on denture care and management of APDs during storage.

### 1.4 Aim

To examine the extent of dimensional instability of acrylic partial denture bases by temperature and humidity in order to establish the dimensional changes that occur during hydrated and dehydrated storage periods.

### 1.5 Objectives

**1.5.1** To investigate the effect of temperature and humidity on the dimensional stability of 9-hour cured acrylic denture bases using a micrometer.

**1.5.2** To investigate the effect of temperature and humidity on the dimensional stability of 1½ -hour cured acrylic denture bases using a micrometer.

**1.5.3** To investigate the effect of storing acrylic denture bases in water on dimensional stability of 9-hour cured acrylic denture bases using a micrometer.

**1.5.4** To compare and evaluate the results of objectives one (*dry-stored*), two *(dry-stored)* and three (*hydrated)* in order to determine the relationship between dry-stored dehydrated period and the control (*hydrated group*) on the dimensional stability of acrylic denture bases.

## 1.6 Hypothesis

$H_0$: There is no significant relationship between the storage media and the dimensional stability of acrylic partial denture bases.

$H_1$: There is a significant relationship between the storage media and the dimensional stability of acrylic partial denture bases.

## 1.7 Assumptions

- The researcher is a qualified dental technologist *(Bachelor of Technology in Dental Technology)* and therefore has the practical 'know-how' knowledge to fabricate acrylic denture base plates.
- All data collection instruments are valid and reliable based upon their frequent use in the dental technology training laboratories at the Durban University of Technology (DUT).
- Acrylic partial denture bases cured for nine hours and is subsequently hydrated on storage will be dimensionally stable.

## 1.8 Delimitations

- The study focused on the curing cycle and storage of APD bases prior to intra-oral use. The adverse intra-oral anatomical factors were not considered.
- The brand of acrylic, polymerisation shrinkage, stress generated by cooling of the flask, shape of the palate and the thickness of the denture base was not considered in this study.

- This study did not evaluate clinical factors such the patient’s adaption of the dentures in terms of denture design and stability.

### 1.9 Structure of Chapters

This dissertation has five chapters. This chapter provided an introduction to the problems associated with the deformation of acrylic partial dentures. Subsequently, this steered the chapter towards the aim and objectives of the study. The concepts hydration and dehydration on the dimensional stability of acrylic partial denture bases emerged.

*Chapter 2* initially introduces the different methods used to replace lost dentition. Design principles and factors contributing to denture base deformation of both complete and partial dentures then follows. This leads to a discussion on PMMA as a denture base material in terms of materials characteristics and polymerisation cycles.

*Chapter 3* details the methodological rationale of the study by describing the experimental research design and quantitative framework.

*Chapter 4* presents the statistical results on the extent of dimensional instability of APD bases. Line graphs, figures and tables are used to support the analytical results. Overall this chapter will provide a rigorous discussion on the effect of different storage media on the fit of acrylic APD bases.

*Chapter 5* forms the final chapter and makes recommendations on the fabrication and storage method to be used in the dental laboratory, and concludes by proposing future directions for research.

# Chapter 2 – Literature Review

## 2.1 Introduction

This chapter reviews literature related to the deformation of acrylic denture bases. An overview of the history of the methods used to replace missing teeth is provided. Subsequently, the differences in design principles between complete and partial dentures are discussed with a specific focus on APDs. This is followed by a discussion on PMMA as a denture base material in terms of characteristics, and polymerisation cycles. The review then focuses on deformation of removable complete and partial denture bases linked to the polymerisation cycles. This chapter concludes by summarising the contents of the review undertaken.

As documented in the literature (Devlin 2002; Rahn, Ivanhoe and Plummer 2009; Anusavice, Shen and Rawls 2013) dentures were used as early as 700 BC. These early dentures were made from human or animal teeth, which were threaded with gold wire to create functional false teeth. Over the years different materials were used in an attempt to replace missing teeth. These included gold, wood, ivory, vulcanite, porcelain and acrylic resin. Over time the materials evolved, with some still being used to date. Generally, and as noted by several authors (Sowter 1986; Nallaswamy 2007; Ghassan 2008; Abdulwaheed 2016) there are three options available to patients to replace missing teeth (Figure 2-1). For the purpose of this study, removable complete and partial dentures will only be discussed.

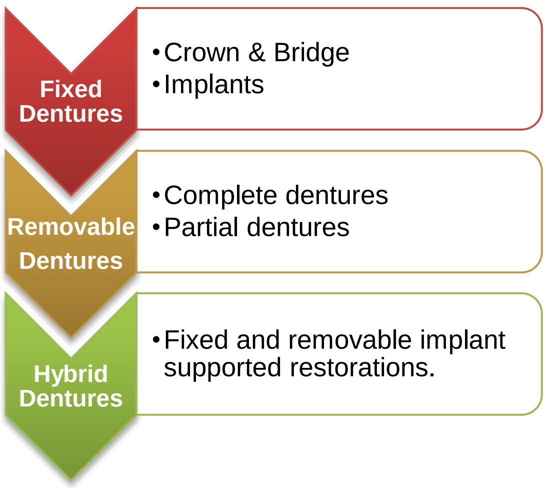


**Figure 2-1:** Treatment options for replacing lost dentition

## 2.2 An Overview of Removable Complete and Partial Dentures

Jones and Garcia (2009) describe a complete denture as a prosthesis that replaces all of the natural dentition and associated structures of the maxillae or mandible, whereas an APD replaces one or more but not all of the dentition. Although the design principles differ from each other, these prostheses are similar in terms of function. Abdulwaheed (2016) explains that a maxillary complete denture is made up of four functional parts. As illustrated in Figure 2-2, the denture borders are the margins of the denture base, which terminate at the junction of the polished surface and base of the denture. The denture base forms the foundation of the denture and helps to distribute and transmit all the forces acting on the denture teeth to the supporting tissue. Artificial teeth are attached to the denture base, which rests on the oral mucosa. Babu, Manjunath and Vajawat (2016) elaborated that artificial teeth enables mastication and speech, while helping to restore the patient’s aesthetics. Abdulwaheed (2016) defined the denture flange as the vertical extension from the body of the denture to the vestibules of the oral cavity. Chen *et al.* (2014) argued that the denture flanges together with its base provide horizontal, anteroposterior and lateral stability. This supports the coronal cross-sectional ‘w-shape’ of the dentures base and flanges in Figure 1-1.

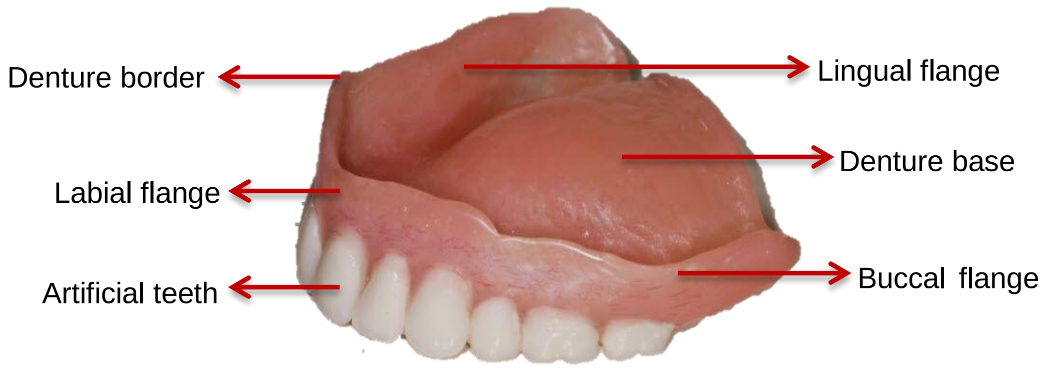


**Figure 2-2:** Components of a maxillary complete denture (Wallace 2011)

In contrast, the stability in an APD can either be tissue-supported or tooth and tissue supported (Jones and Garcia 2009). In a tooth and tissue supported prosthesis (Figure 2-3), retention is gained from the bone covered by the oral mucosa and clasps, which actively engage the abutment teeth. Prasad *et al.* (2013) define abutment teeth as teeth that act as an anchor on which the clasps are placed to support and stabilise the APD. This supports the coronal cross-sectional 'n-shape' of the dentures base in Figure 1-2. According to Wilson (2009) the associated benefits of an APD is that it is economical, easy to adjust and is aesthetically pleasing.

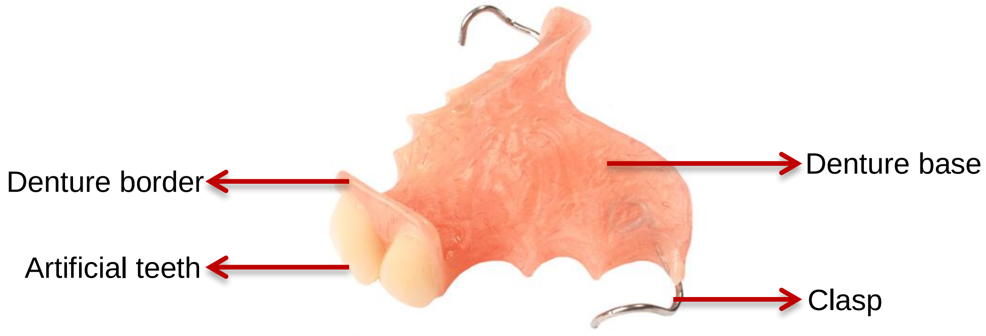


**Figure 2-3:** Components of a maxillary acrylic partial denture (APD) (Wilson 2009: 431)

Apart from a supporting function, the denture base of an APD joins the clasps and artificial teeth into a single functioning unit. Moreover, the denture base evenly distributes the load over the underlying mucosa and acts as a stabiliser for the denture by resisting the horizontal forces (Indian Dental Academy 2014). Wilson (2009) stressed that the design of the APD is of the utmost importance in order to succeed both biologically and mechanically. Equally significant, and as argued in several studies (Nallaswamy 2007; Wilson 2009; Indian Dental Academy 2014), the clasp must contact the abutment tooth at the survey line[1] (Figure 2-4) to increase support and prevent poor oral hygiene in terms of food being trapped between the clasp and the tooth. Critically, if the denture terminates below the survey line a gap will occur between the denture and the tooth thereby causing denture movement.

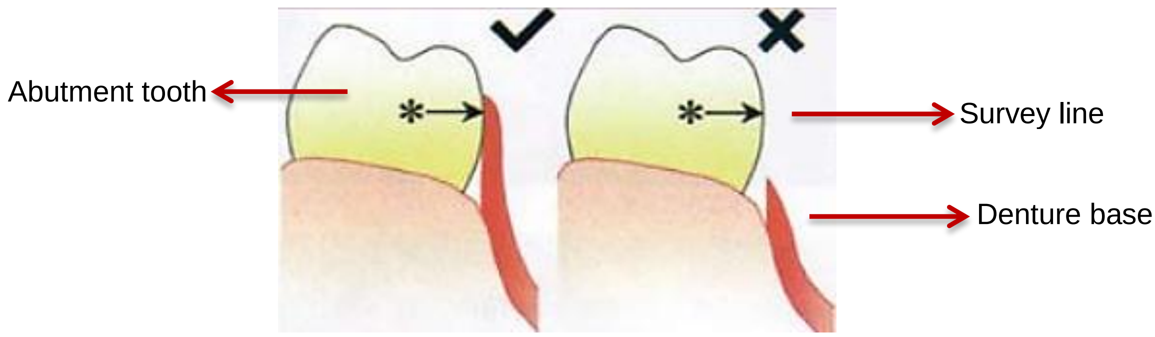


**Figure 2-4:** APD base must contact the abutment tooth at the survey line (Wilson 2009: 432)

[1] A survey line is a line marked on an abutment tooth that indicates the greatest circumference when viewed from a horizontal plane

In addition, Allen and McCarthy (2003) and Georgieva *et al.* (2016) pointed out that the various physical factors affecting the retention of a maxillary denture are adhesion, cohesion and interfacial surface tension. Adhesion is the physical attraction between unlike molecules, whereas cohesion is a molecular attraction between like molecules. According to Georgieva *et al.* (2016) interfacial surface tension significantly contributes to the retention of maxillary dentures and is in direct proportion to the viscosity of the saliva, denture base area and the velocity of the dislodging forces. They, together with Darvell and Clark (2000), further elaborated that good adhesive and cohesive forces enhance interfacial surface tension. An increased space between the denture base and mucosa will decrease the interfacial surface tension. When there is a close adaption between the denture base and the mucosa, forces of cohesion will act to keep the salivary film intact. Furthermore, forces of adhesion and surface tension will act to attract saliva to the denture and the denture bearing tissue thereby increasing retention of the denture fit intraorally. If there is a misfit or deformation of a maxillary APD, the forces of adhesion, cohesion and interfacial surface tension will not be achieved. Consequently, the posterior palatal seal of the APD is weak (Raman 2017). This is pertinent to the study as it underpins the dimensional instability of APD denture bases. From a clinical perspective a weak posterior palatal seal leads to the clasps being subjected to more forces, which could exert unwanted pressure on the abutment teeth and there by compromising their function. This may cause patient discomfort, loss of abutment teeth and ultimately failure of the prosthesis (Darvell and Clark 2000; Nallaswamy 2007; Raman 2017; Georgieva *et al.* 2016).

## 2.3 Factors contributing to Dimensional Instability of Removable Complete and Partial Denture Bases

According to Khalid and Arafa (2016) a successful denture should have dimensional stability in order to enhance chewing efficiency, increase the patients comfort and prevent injury to the oral tissue. As outlined by McCord and Grant (2000: 128) there are various factors that affect the dimensional instability of removable complete and partial dentures, namely:

- adverse intra-oral anatomical factors: atrophic mucosa or palate shape and depth;

- clinical factors e.g. poor denture design and stability;
- technical factors such as failure to preserve the peripheral roll on a master cast and patient adaptional factors;
- processing procedure factors such as the type of material used to fabricate the acrylic denture base, polymerisation shrinkage, stress generated by cooling of flasks, length of the curing cycles and storage of the denture base post manufacture.

For the purpose of this study, the some of the above mentioned factors have been delimited. The length of the curing cycles and storage of the denture base post manufacture were considered to be relevant as key factors for dimensional instability of RPDs in this study. Savabi *et al.* (2015) asserted that processing shrinkage and expansion of dental acrylic due to water absorption is an inevitable weakness as it affects denture retention and stability. Arora *et al.* (2011) reported that shrinkage of dentures also occurs during storage. Resonating with them, Nair *et al*. (2013) pointed out that shrinkage is generally noticeable in the palatal and posterior palatal seal areas. When the denture base was placed on the stone model after 24 hours after being processed, they observed that the strain released in the maxillary denture caused the flange to be drawn inward (Figure 2-5). This causes a premature contact of the denture with the stone model thereby elevating the palatal surface of the denture base away from the model. In the mouth a gap between the supporting tissue and denture base results. Saini *et al.* (2016) reported that denture bases contract when left in open air and a dry place. They therefore recommended that the denture base be stored in water when not in use.

Rimple *et al.* (2011) confirmed that the greatest change in dimension due to water sorption takes places during the first seven days. Arora, Sangur and Dayakra (2011) reported that deformation in maxillary complete denture bases increased over time, particularly after the seventh day of fabrication. Consani *et al.* (2011) demonstrated that after 24 weeks anteroposterior deformation was observed in maxillary complete dentures. Lim and Lee (2016) also revealed that deformation was found in the bilateral posterior buccal flange area, and deformation was also found in the posterior palatal seal area. More recently, Raman (2017) confirmed that the greatest deformation of maxillary dentures occurred in the first month and gradually subsided at the end of the third month. The time frames, together with the deformation sites reported by the aforementioned authors, were considered in the storage and testing of the specimens, which are described in the next chapter. Notwithstanding this, it can further be gathered that an element underpinning processing shrinkage is the denture base material, which is discussed in the next section.

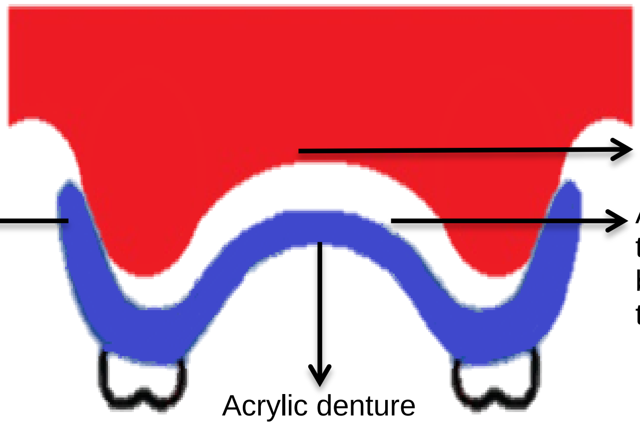


**Figure 2-5:** A gap forms between the supporting tissue and denture base during shrinkage

## 2.4 Poly Methyl Methacrylate Denture Base Material

Since the mid-1940s to date, PMMA acrylic resins are commonly used to fabricate APDs. Anusavice, Shen and Rawls (2013) outlined that PMMA is a powder-liquid system where the powder contains a pre-polymerised polymer and the liquid contains non-polymerised methyl methacrylate (monomer). Hussain (2004) noted that the polymer and monomer are mixed using the recommended powder-liquid ratio of 3:1 by volume or 2:1 by weight, to form a workable mass. Poly methyl methacrylate solidifies during polymerisation either through heat, light or chemical activation (Anusavice, Shen and Rawls 2013). Heat cured acrylic resin was used to fabricate the specimens in this study.

Heat cured resins are resilient plastics formed by joining multiple methyl methacrylate molecules or 'mers'. Pure PMMA is a colourless transparent solid, which is used to provide the necessary shades for dental use. Some of the reported disadvantages of PMMA include polymerisation shrinkage; the short life-span of the material; low impact strength and brittleness, which can cause the

APD to fracture (Anusavice, Shen and Rawls 2013; Bonsor and Pearson 2013; Kawaguchi *et al.* 2014; Muzaffar 2014; Geminiani 2016). Importantly, Tuna *et al*. (2008) asserted that release of the residual monomer causes dimensional instability, which leads to crack formation and ultimately the denture fracturing.

Ghassan (2008) noted that low residual monomer content was obtained by polymerising the denture bases for a prolonged period and then storing the denture bases in distilled water for at least one day. Kawaguchi *et al.* (2014) confirmed that a low level of residual monomer improves the tensile strength and water absorption of the denture base resin. Dandekeri *et al.* (2014) emphasised that the strength of the denture base decreases when stored in water for a week, due to the release residual monomer. Consequently, the denture becomes brittle and fractures easily. The advice given by the aforementioned authors is pertinent to this study in terms of the deformation patterns of the APDs.

Equally important, the aim of the polymerisation cycle is to raise the temperature to a point at which sufficient benzoyl peroxide decomposes to produce free radicals (Anusavice, Shen and Rawls 2013). Each free radical rapidly reacts with an available monomer molecule to initiate chain growth polymerisation. As posited by Anusavice, Shen and Rawls (2013) the benzoyl peroxide in the polymer is responsible for the polymerisation process and is termed the initiator. Benzoyl peroxide decomposes rapidly when heated above 60ºC. According to McCabe and Walls (2013) a rapid rise in temperature produces large radicals and as a result, many growing polymer chains are formed. In turn this reduces toughness of the denture base. By contrast, and as reported by Consani *et al.* (2014) longer polymerisation cycles result in much tougher denture bases. The next section briefly discusses the polymerisation cycle and its impact on denture deformation.

## 2.5 Polymerisation Cycles *(Length and Temperatures and its Relation to Denture Deformation)*

Anusavice, Shen and Rawls (2013) define the polymerisation cycle, or curing cycle, as the heating process used to control polymerisation. As previously mentioned, PMMA denture bases should be processed at a constant temperature in a curing bath at 74ºC for nine hours. Since PMMA denture bases undergo an exothermic reaction, the amount of heat created may affect the properties of the processed denture base. As a result of this process, denture resins should not exceed the boiling point of the monomer (100.8ºC) because of the adverse effects on the dimensional stability of the processed resin. Furthermore, and as argued by Anusavice, Shen and Rawls (2013), the polymerisation process must be controlled by slowly heating the resin during the polymerisation cycle. He therefore recommends using a 9-hour curing cycle. Contrary to this, however, a reduced curing cycle is used. In this reduced curing cycle the denture flasks are placed in 45ºC water and brought to boiling point. The total time for this cycle is 1½-hours (Harrison and Huggett 1992; Consani *et al.* 2014*;* Nisar, Moeen and Hasan 2015). The two different curing cycles will be elaborated further in the next chapter.

A noteworthy point is that South African dental technicians generally use a reduced curing cycle in order to save laboratory processing time. Importantly, and as reported by Jadhav, Bhide and Prabhudesai (2013), a reduced curing cycle results in a high level of residual free monomer content in the denture base. Rashid, Sheikh and Vohra (2015) explained that during a short curing cycle not all monomer molecules are converted into polymers. As a result unreacted residual monomer remains unpolymerised. Another problem outlined by Consani *et al.* (2006) and Tuna *et al.* (2008) is that water sorption results in expansion of the denture base due to water penetration within the acrylic resin molecules. Ultimately, and according to Miessi *et al.* (2008) and Gharechahi *et al.* (2014), water sorption and incomplete denture polymerisation contribute to the dimensional changes of APDs post-polymerisation.

In addition, Consani *et al.* (2002) clarified that deformation of the denture base occurs during cooling and after the denture base is separated from the stone model. As explained by Lim and Lee (2016), this can be further exacerbated if denture bases are stored in a dry environment for 28 days. Notwithstanding this, Barbosa, Fraga and Goncalves (2001) noted that the weight of denture bases stored in water increased and the weight of the denture bases decreased when placed in a dryer. This further indicates that the denture base undergoes dimensional change regardless of the environment it is in. Miessi *et al.* (2008) reported that cyclic drying and wetting of the denture base for a period of six months caused dimensional changes between the denture base and the stone cast. This phenomenon of cyclic drying and wetting is termed crazing. Bonsor and Pearson (2013) defined crazing as the presence of fine cracks on the surface of the acrylic that are set up by mechanical stresses within the denture base as it contracts and expands during the drying and wetting cycles. This is pertinent to the study in terms of ensuring that the PMMA specimens are free from crazing.

In summary and from a dental technology design and denture processing perspective, this chapter clarified the differences between removable complete and partial dentures. In particular, the factors contributing to dimensional instability of PMMA denture bases were outlined. This led to a brief discussion on PMMA as a denture base material, which appropriately linked to the various polymerisation cycles and the relationships to denture deformation. The next chapter describes the research design and methodology used in this study.

# Chapter 3 - Research Design and Methodology

This chapter details the quantitative research approach used by describing the experimental research design and methodology. Initially, this chapter explains the reasons for adopting the aforementioned research design. The sample preparation and analysis of the specimens are described in depth.

## 3.1 Introduction and Background of the Research Methodology

Laboratory and clinical observations together with inductive reasoning provided the basis for initiating this study. Contrary to using the recommended 9-hour curing cycle to minimise the unavoidable thermal expansion on heating, contraction on cooling and polymerisation shrinkage (Anusavice, Shen and Rawls 2013, Negreiros *et al*. 2009; Manappallil 2016), dental technicians from industry (in a telephone conversation on 15 March 2015, Mr Y. Boodhun and Mr C. Polinski) polymerise dentures using the shorter curing cycle that is less than two hours. Notwithstanding this, and in a telephone conversation on 15 March 2015, dentists Dr M. T. Khan and Dr R. Mohamed indicated that dentures are generally dry-stored in the dental rooms for approximately two weeks. In conjunction with acrylic dentures shrinking linearly as much as approximately 0.5% after polymerisation (Lim and Lee 2016; Nair *et al.* 2013), the common dry-store practice exacerbates the deformation of dentures. Ultimately this compromises the stability and retention of the dentures intraorally.

As this study aimed to determine the effect of dehydration on the dimensional stability of acrylic partial dentures, an experimental research design within a quantitative framework was used. Creswell (2013: 13) clarified that experimental research entails *"…providing a specific treatment to one group and withholding it from another…"* in order to determine *"…how both groups scored on an outcome"* Hypothesis testing is therefore used in order to reach valid conclusions about the independent and dependant variables (Agarwal 2006). As mentioned in Section 1.6 in Chapter One, the hypotheses for the study were:

- $H_0$: *There is no significant relationship between the storage media and the dimensional stability of acrylic partial dentures.*
- $H_1$: *There is a significant relationship between the storage media and the dimensional stability of acrylic partial dentures.*

The following sections describe in detail the experimental research methodology used in this study.

### 3.2 Sample Size and Preparation of Specimens

Cohen, Manion and Morrison (2011) argued that there is no specific number for the correct amount of samples to be used. The sample size depends on the purpose of the study and the level of accuracy needed. They advised, however, that a sample size of 30 is considered appropriate. In line with their advice, and as illustrated in Table 3-1, there were three sample groups of ten specimens in each group (n=30), which were polymerised using the different curing cycles.

**Table 3-1:** Number of Specimens and Curing Cycles

| Sample Group | Number of Specimens | Curing Cycles |
|---|---|---|
| **Control (hydrated)** | 10 | Cured for 9-hours at 74ºC. |
| **Group 1 (dehydrated)** | 10 | Cured for 9-hours at 74ºC. |
| **Group 2 (dehydrated)** | 10 | Cured for 1½-hours at 45ºC - 100ºC. |

The fabrication of the specimens are detailed below.

- Initially a maxillary cast (Figure 3-1**A**) obtained from the Dental Clinic (DUT) was duplicated using silicone moulds (Mold Max® 30). These moulds (Figure 3-1**B**) facilitated the duplication of 30 yellow stone models (gypsum calcium sulphate α-hemihydrate) (Dentsone™, KD, Saint Gobain).

- Using the palate area of the model (Figure 3-2**A**) a maxillary acrylic base plate (Figure 3-2**B** - Vertex™ Orthoplast Dental B.V, Netherlands) was subsequently fabricated. The acrylic base plate was used as a template to outline the design on 30 models prior to fabricating the 30 wax patterns (Figure 3-3 - Kemdent®, Purton, Swindon, Wiltshire, United Kingdom).


**Figure 3-1:** Duplication of Model:
**(A)** Maxillary cast; **(B)** Silicone moulds

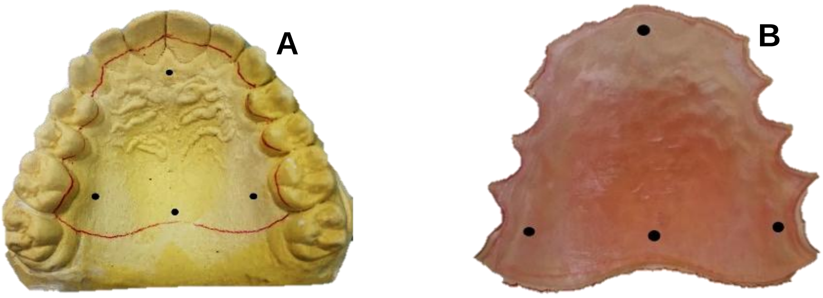


**Figure 3-2:** Preparation of specimens:
**(A)** Template design; **(B)** Acrylic base plate

**Figure 3-3:** Fabricated Wax patterns

- All wax patterns were flasked and packed. According to Anusavice, Shen and Rawls (2013) flasking involves placing the wax pattern in a denture flask and filling it with freshly mixed dental stone. After the dental stone has set, the flask is immersed in boiling water to remove the wax. In contrast, packing is the placement and adaptation of the denture base resin within the mould cavity.

- Thirty denture base plates were fabricated using heat-cured denture base acrylic resins (Vertex™- Dental B.V, Netherlands). As shown in Table 3-1, the recommended 9-hour curing cycle by Anusavice, Shen and Rawls (2013) was used for Group 1 and the Control group. The 1½-hour short curing cycle (Anusavice, Shen and Rawls 2013), which is also commonly used by qualified dental technicians from industry, was used to cure the acrylic specimens for Group 2.

- As advised by Carr and Brown (2015) all APD base plates were finished by trimming, pumicing and polishing until they were 2mm thick and had a high shine (Figure 3-4). A noteworthy point is that a 2mm thickness of the denture base helps to reduce intra-oral problems associated with phonetics and patient discomfort, while the high shine reduces bacterial colonisation on the denture base.

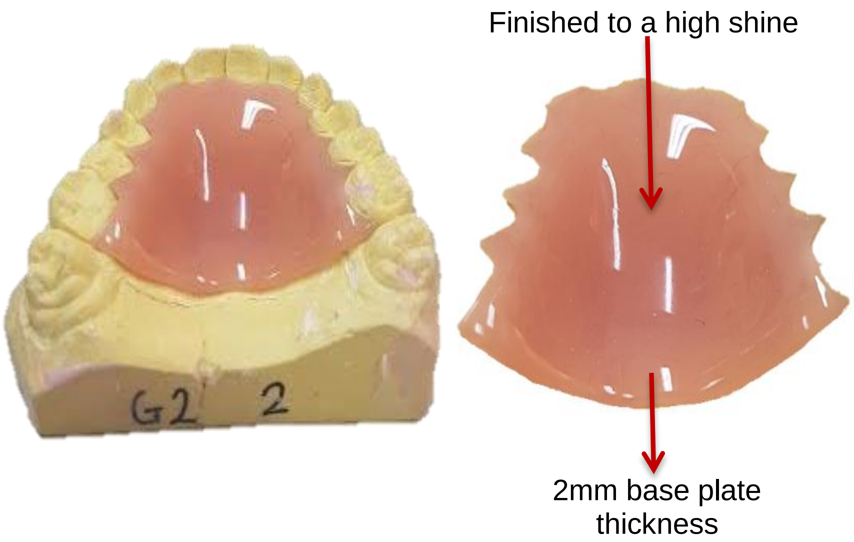


**Figure 3-4:** Acrylic Partial Denture Base Plate

### 3.3 Storage of Specimens

As this study was premised on the effect of dehydration on the dimensional stability of acrylic partial dentures, knowledge of incubators (Adid 2008; Moore 2015; Sheik 2015) was acquired to construct a customised incubator to store the APD base plates for Groups 1 and 2 (Figure 3-5). The incubator, which was constructed using chipboard (45cm x 35cm x 30cm), consisted of a fan (Cooler Bank™, Chiefly Choice Limited Company, Shenzhenshi, Canton, China) to cool the air and two 100w light bulbs to increase the temperature within the incubator. The Relative Humidity (RH) within the unit was controlled using 245g of silica gels (Figure 3-6 Mystify® dehumidifier).

**Table 3-2:** Storage the PMMA Specimens

| Sample Groups | Methods of Storage |
|---|---|
| **Control** | Hydrated in a water bath at 37ºC for 28 days. |
| **Group 1** | Dehydrated for 28 days with the temperature regulated to 21ºC and 40% humidity. |
| **Group 2** | Dehydrated for 28 days with the temperature regulated to 21ºC and 40% humidity. |

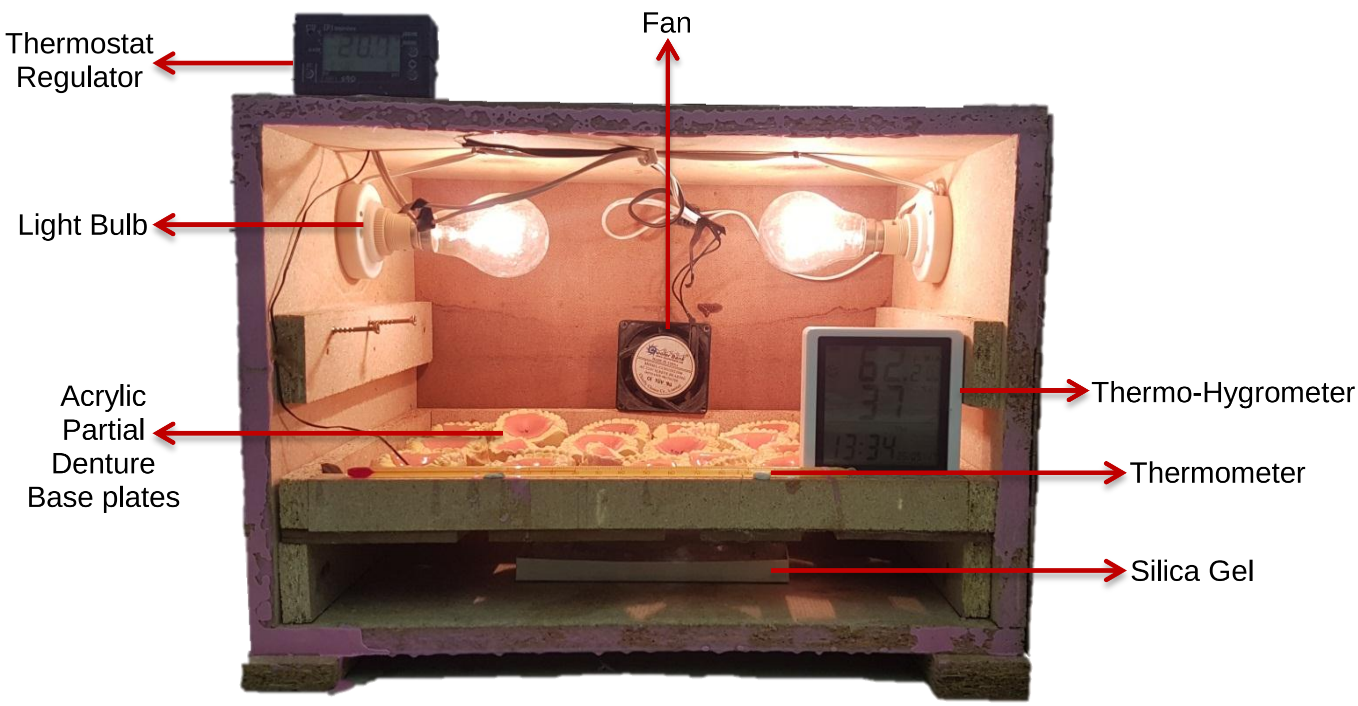


**Figure 3-5:** Custom made incubator


**Figure 3-6:** Silica gels

As advocated by Weintraub and Tétreault (2003), the equation below was used to determine the quantity of silica gel needed in the temperature unit:

$$Q = (Ceq \times D) \times V \times (N \times t) / (MH \times F)$$

Where:

**Q** = Kilograms of silica gel required.

**Ceq** = Concentration of water vapour at saturation (at $21^{o}$ C, a cubic meter of air holds 18.5 grams of water vapour at saturation).

**D** = The difference between the external RH and RH within the case. External RH is based on the average maximum range of RH fluctuation within the room. Internal RH range is 40-50% and the exterior range is approximately 30%-70% RH (20% or 0.2)

**V** = The volume of the case, expressed in cubic meters.

**N** = The number of air exchanges per day (one air exchange per day for a typical moderately sealed case).

**t** = The maximum number of days that the case should remain within an acceptable range of RH.

**MH** = The average amount of water (in grams) that is gained or lost by one kilogram of silica gel for each 1% change in RH. Using regular density silica gel (MH= 2).

**F** = The acceptable maximum range of RH fluctuation within the case (40-50% = 10).

**Q** = $(18.5 \times 0.2) \times 0.00004725 \times (1 \times 28) / (2 \times 10) = 245g$

Using a thermostat (Carel™ s90 Tp1, Padova, Italy) the temperature in the unit was regulated to 21ºC and kept at 40% humidity. A Thermo-Hygrometer (Flus® FL-201, Shenzhen Flus® Technology, China) was also used to monitor the relative humidity within the unit. This was done according to the South African National Standard 861 (2008: 6), which outlines that test specimens in a laboratory environment for denture base polymers need to be prepared and tested at 23 ±2ºC and 50 ±10% relative humidity. A critical point to be noted is that the aforementioned temperature and humidity levels simulate the average summer season in South Africa, particularly taking into consideration the average summer temperatures and humidity in the Dry Great and Upper Karoo, Kalahari Bushveld and Kalahari Highveld (Figure 3-7). The humidity and temperature levels of the various inland areas were also considered (Table 3-3). Several authors (Ristic and Carr 1987; Barclay and Walmsley 1998; Devlin 2002; Rahn, Ivanhoe and Plummer 2009; Rosdahl and Kowalski 2009; Lim and Lee 2016) recommend that dentures should be stored in water when not in use, in order to minimise distortion and shrinkage. The acrylic denture bases of the control group were therefore stored in water.

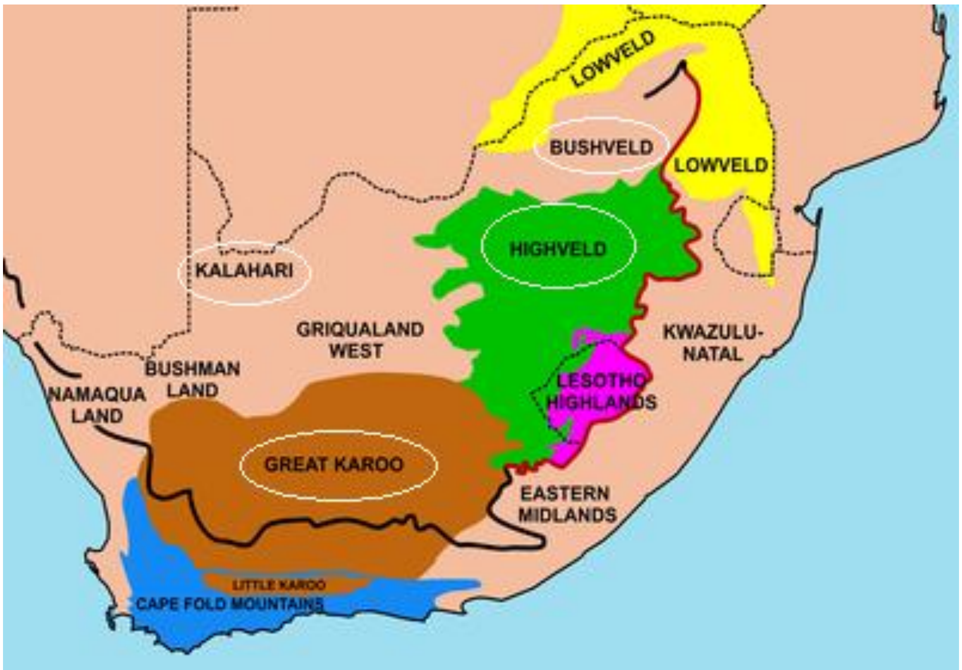


**Figure 3-7:** Regions of South Africa (Oggmus 2014)

**Table 3-3:** The Average Summer Temperatures and Humidity in Some Inland Areas in South Africa *(Adapted from Weatherbase 2015)*

| Area | Average Summer Temperature (ºC) | Average Summer Humidity (%) |
|---|---|---|
| **Beaufort West** | 21 | 43 |
| **Bethlehem** | 19 | 46 |
| **Ermelo** | 23 | 59 |
| **Estcourt** | 19 | 58 |
| **Kimberley** | 20 | 44 |
| **Kuruman** | 22 | 46 |
| **Ladysmith** | 20 | 58 |
| **Lichtenburg** | 21 | 56 |
| **Middelburg** | 19 | 43 |
| **Nelspruit** | 22 | 66 |
| **Newcastle** | 21 | 66 |
| **Prieska** | 20 | 37 |
| **Springbok** | 21 | 47 |
| **Upington** | 22 | 35 |
| **Vryburg** | 23 | 43 |
| **Welkom** | 20 | 52 |
| **Average** | **21** | **50** |

**Note:** The humidity levels of the various South African regions were considered, however the average humidity of the highlighted areas in 'grey', which are situated in the Dry Great and Upper Karoo, Kalahari Bushveld and Kalahari Highveld regions were used. This temperature range is generalizable to arid regions of lower humidity. These areas are more likely to experience the effects of dehydration during storage and stand to benefit more from this study design.

Equally important, telephonic conversations with established dentists such as Dr Khan and Dr Mohamed on the 15 March 2016, together with a study by Ristic and Carr (1987) and Garg and Shenoy (2016), guided the duration of storage of the acrylic denture base plates in this study. Ristic and Carr (1987) measured the water absorption of complete dentures on days 1, 2, 4, 14, 21 and 28. Recently, Garg and Shenoy (2016) measured the water absorption of complete dentures on days 4, 7, 11 and 15. It is to be noted that there are no studies available on APD bases and therefore a more formal guideline on APD bases is required. Notwithstanding this, the aforementioned dentists confirmed that the placement of an APD in the patient's mouth could take place anytime from the day the prosthesis is fabricated up to a month post-fabrication. The fit of the APD bases were therefore measured immediately after fabrication (day 1) and subsequently measured on days 2, 7, 14, 21 and 28. It is to be noted that the measurements taken on day 1 are recoded to indicate the effect of curing. Equally important, owing to the diversity of variables linked to polymerisation shrinkage this was considered a delimitation of this study and not investigated further

### 3.4 Measuring the Fits of the Denture Bases

The silicone method used by Ghani *et al*. (2010) was followed in terms of measuring the fit of the APD base plates to the models. The process entailed mixing 100g of Part A Silicone (Mold Max® 30) with10g of Part B liquid (Fast cat® 30) for three minutes. The mixture was then poured onto the palatal surface of the maxillary cast and the APD base plates were fitted onto the cast using finger pressure (Figure 3-8). Following setting, a scalpel was used to trim the excess silicone. Subsequently the APD base plates were carefully removed from the cast. The silicone layers were transported to the Mechanical Engineering Department (DUT) for testing in an airtight container to prevent distortion of the silicone. Using a micrometre, which was calibrated before the beginning of every set of measurements for the duration of the study (Figure 3-9 - Mitutoyo® S293, America Corporation, Illinois, United States of America), the thickness of the silicone layer was measured with the assistance and guidance of Mr Govender (Technology Station, DUT).

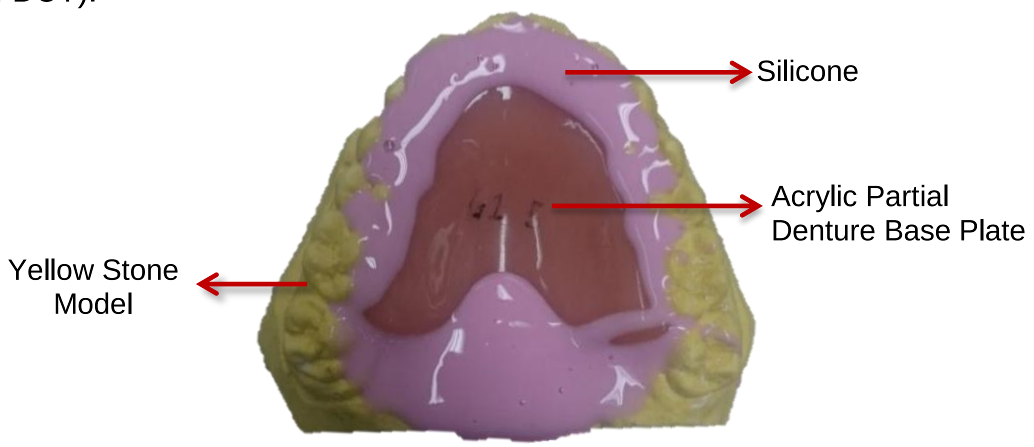


**Figure 3-8:** Silicone Placed between the Acrylic Partial Denture Base Plate and Model


**Figure 3-9:** Mitutoyo™ micrometre

In determining the dimensional accuracy of heat cured maxillary complete dentures, Babu *et al.* (2014) used a thermoplastic denture base plate to mark seven reference areas, namely: incisive papilla; canine region on either side; midpoint of tuberosity on either side; midpoint of the line joining the two tuberosity; midpoint between the line joining the incisive papilla; and midpoint of the line joining the two tuberosity.  As illustrated in Figure 3-10, an indelible pencil was used to mark four reference areas that is the incisal papilla, the first molar region on the 16, the first molar region on the 26 and the deepest part of the midline area posteriorly were marked on each stone model.

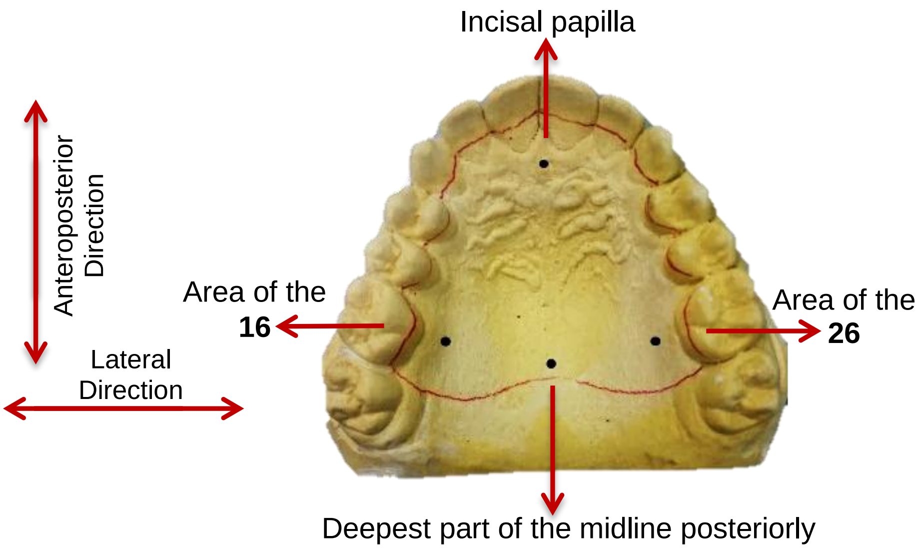


**Figure 3-10:** Reference Areas Measured

Although Lim and Lee (2016) reported no deformation in the sagittal section of the maxillary complete denture base, bilateral contraction was also observed in the frontal section of the denture.  This further supports the rationale for using the aforementioned reference areas (Figure 3-10), particularly in determining whether deformation occurred mostly in an anteroposterior direction, laterally, or in both directions.

### 3.5 Data Analysis

Linda, Mason and Marchal (2002) elaborated that descriptive statistics describe, organise and summarise a particular set of quantitative data. Although such statistics make no inference or predictions they are, however useful in summarising results for an experiment. With reference to the inferential statistical analysis, Johnson and Christensen (2012) explained that inferential statistics, by contrast, use the laws of probability to make inferences and draw statistical conclusions about the sample data. In testing the hypothesis, as outlined in Section 1.5, the data collected was statistically analysed using SPSS® (Version 24) and Graph Pad Prism® (Version 5.0). Various graphs, together with other descriptive measures for the quantitative data, are used to present the descriptive statistics in the next chapter. Using SPSS® (Version 24), a Kruskal-Wallis test was used to determine if there were any significant differences between the reference areas within the groups. The Kruskal-Wallis is a nonparametric test and can be used for testing any significant differences between two or more groups of independent variables on a continuous dependant variable (Lund and Lund 2013). The Kruskal-Wallis test does not indicate which specific groups of the independent variables are significantly different from each other, therefore a Dunn's multiple comparison test was also conducted. The Dunn's multiple comparison is a *post hoc* test and can be used to identify which specific means are significantly different. The level of significance used to determine the mean differences was 0.05.

In addition, utilising Graph Pad® Prism (Version 5) a slope test nonlinear regression analysis with a straight-line model was used to determine the degree of deformation of acrylic partial denture bases. This was done by comparing and evaluating the results of the dry-stored dehydrated *(Objectives 1 and 2)* and hydrated *(Objective 3)* acrylic partial denture bases. An F-test was also used to compare the slopes of the three groups *(level of significance = 0.05)*. A noteworthy point is that while the $\mathbf{r^2}$ provides an estimate of the strength of the relationship between the observed values and the predicted values, it does not provide a formal hypothesis for this relationship. Overall the F-test determines whether this relationship is statistically significant, as well as simultaneously assessing multiple coefficients simultaneously. If the p-value for the F-test is less than the significance level ($p$<0.05), it can be concluded that the $\mathbf{r^2}$ value is significantly different from zero. This simply means that there is a significant relationship between the independent and dependant variables.

### 3.6 Validity and Reliability

According to Cohen, Manion and Morrison (2011) validity in quantitative research can be improved through careful sampling, appropriate and reliable instrumentation and suitable statistical treatment of data. Generally, internal validity is achieved by manipulating the independent variable (Agarwal 2006), which in this study was the storage of the acrylic denture base plates in order to measure the discrepancies in the fit (dependent variable). Internal validity was maintained by ensuring that the design of the experiment closely followed the principle of cause and effect (Johnson and Christensen 2012). The principles of cause were temperature, humidity and curing cycles in order to ascertain the effect on the fit of the acrylic denture base plate. Validity for storage of the specimens was achieved by using the procedures outlined in the SANS Standard 861 (2008) for Denture base polymers. Following Anusavice, Shen and Rawl's (2013) recommendations for manufacturing acrylic denture bases further supports validity for duplication of the acrylic base plates. The Thermo-Hygrometer was purchased from Shenzhen Flus Technology (EN 612328-1: 2013) and was calibrated according to recommended standards for thermo-hygrometers (Appendices 1a and 1b). Equally important the calibration of the micrometer (Appendix 2a and 2b) further supports the validity of the results. The micrometer was calibrated using a Coordinate Measuring Machine and thereafter checked with a 5mm calibration disk before the start of every set of measurements for the duration of the study.

Cohen, Manion and Morrison (2011) clarified that the reliability in quantitative research is the measure of dependability, consistency and replicability over time and over instruments. Using a temperature control unit helped to standardise and control the conditions under which the acrylic denture base plates were stored. In terms of reliability for temperature the thermo-hygrometer was verified for the duration of the experiment by cross-checking the temperature readings with a mercury thermometer (Appendix 3). The micrometer was verified in accordance with the method above at the start of every set or cycle of measurements for the duration of the study. According to Gwert (2014), interrater reliability is the degree of agreement among repeated administrations of a diagnostic performed by a single rater. Interrater reliability was maintained by measuring the reference areas of each sample group and obtaining a mean value for each reference area. Furthermore, the results between individual denture bases within each sample group demonstrated no significant difference. The definition of dependability, replicability, and consistency is the stability of data over time, which can be reproduced and remains the same. Based on the forgoing definitions it can be inferred that the results of this study are reliable. The detailed results of the experiment are presented in Chapter 4.

Overall, this chapter has explained the research paradigm and experimental work conducted in this study. The subsequent chapters provide a detailed discussion of the results.

# Chapter 4 – Results and Discussion

This chapter presents the results and discussion of the study. The aim of the study was to investigate the extent of dimensional instability of acrylic partial denture bases by temperature and humidity. As outlined in Chapter 3, Section 3.4, the dimensional accuracy of the acrylic partial denture bases was measured in the incisal, midline and first molar (16 and 26) areas. The Kruskal-Wallis non-parametric test and Dunn's Multiple Comparison test was used to analyse the degree of deformation in the areas mentioned above. The slope test was further used to compare the deformation trends of each group (Graph Pad Prism® Version 5). Tables and figures have also been included to strengthen the explanation of the statistical results. A discussion of the relationship between the storage period, media used and the dimensional fits of the denture base plates then follows. This chapter concludes with a summary of the data analysed.

## 4.1 The Effect of Temperature and Humidity on the Dimensional Stability of Acrylic Denture Bases Cured for 9-Hours

Table 4-1 shows the mean values of dimensional deformation measured at the incisal, midline and first molar (16 and 26) areas of the ten APD bases, which were cured for 9-hours and stored in an incubator for 28 days. Figure 4-1 illustrates the extent to which temperature and humidity affected the dimensional stability of the 9-hour cured APD bases. Table 4-2 depicts the differences in the dimensional deformation of APD bases measured from the point of immediate fabrication *(day 1)* to each storage interval at 2, 7, 14, 21 and 28 days. The inherent porous characteristics of APD bases, together with the contraction that occurs when exposed to an open air and dry environment, adversely affects the dimensional fit of APD bases. It is to be noted that the highest deformation measured over the 28-day storage period was in the deepest part of the midline area posteriorly (0.0470mm), followed by the area of the 16 (0.04578mm). Consistent with Nair *et al*. (2013), Hamouda *et al.* (2016) and Lim and Lee (2016), the increased curvature of the tissue of the posterior palatal region could have attributed to the highest deformation recorded.

**Table 4-1:** Mean values of deformation of Partial Denture Bases (9-hour cure)

| Storage Intervals (day/s) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 1 | 0.2435 | 0.2882 | 0.2539 | 0.2522 |
| 2 | 0.2532 | 0.3289 | 0.2615 | 0.2663 |
| 7 | 0.2613 | 0.3153 | 0.2875 | 0.2690 |
| 14 | 0.2768 | 0.3281 | 0.3016 | 0.2793 |
| 21 | 0.2959 | 0.3417 | 0.3103 | 0.3030 |
| 28 | 0.3201 | 0.3640 | 0.3375 | 0.3111 |

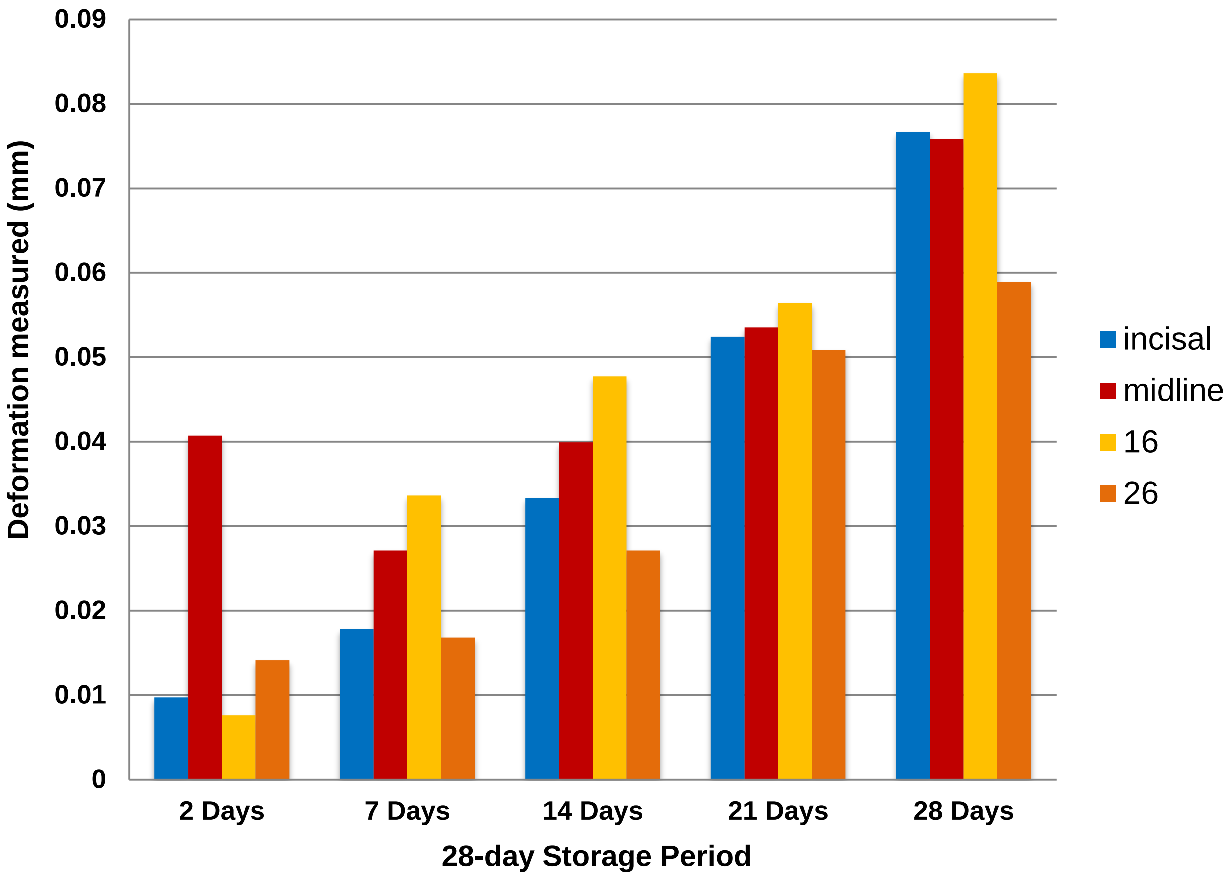


**Figure 4-1:** Trends in Dimensional Deformation of Acrylic Partial Denture Bases Cured for 9-hour and stored in an incubator over 28 days

**Table 4-2:** Deformation of Acrylic Partial Denture Bases (9-hour cure) measured from immediate fabrication to each storage interval

| Storage Intervals (days) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 2 | 0.0097 | 0.0407 | 0.0076 | 0.0141 |
| 7 | 0.0178 | 0.0271 | 0.0336 | 0.0168 |
| 14 | 0.0333 | 0.0399 | 0.0477 | 0.0271 |
| 21 | 0.0524 | 0.0535 | 0.0564 | 0.0508 |
| 28 | 0.0766 | 0.0758 | 0.0836 | 0.0589 |
| **Deformation Measured** | **0.03796** | **0.04740** | **0.04578** | **0.03354** |

Although the results in Table 4-3 revealed no statistical differences ($p > 0.05$), Figure 4-1 clearly shows the dimensional deformation of the APD bases in the incisal, midline and first molar (16 and 26) areas increasing over the 28-day storage period. It must be noted that from days two to seven there was an unexpected decrease in deformation of -4.13%[2] in the midline area. This indicates that deformation occurs towards the midline area and away from the lingual palatal slopes in APD bases. In contrast to complete dentures, deformation of APD bases occurs towards the midline area.

## 4.2 The Effect of Temperature and Humidity on the Dimensional Stability of Acrylic Partial Denture Bases Cured for 1½-hours

Table 4-4 illustrates the mean values of dimensional deformation measured at the incisal, midline, and first molar (16 and 26) areas of the ten APD bases, which were cured for 1½-hours and stored for 28 days in an incubator. This is supported by Figure 4-2, which shows the extent to which temperature and humidity affected the dimensional stability of the APD bases cured for 1½-hours. Table 4-5 depicts the differences in the dimensional deformation of APD bases measured from the point of immediate fabrication *(day 1)* to each storage interval at 2, 7, 14, 21, and 28 days. A point that deserves to be mentioned is that the highest deformation measured over the 28-day storage period was in the deepest part of the midline

[2] Note: This percentage was calculated using the following formula:

$$\frac{Mean\ value\ of deformation\ for\ Day\ 7 - Mean\ value\ of\ deformation\ for\ Day\ 2}{Mean\ value\ of\ deformation\ for\ Day\ 2}\ \mathrm{X}\ 100$$

area posteriorly (0.08022mm), followed by the area of the 16 (0.07948mm). As previously mentioned, the increased curvature of the tissue at the posterior palatal region is more likely to have contributed to the dimensional deformation of the denture bases (Nair *et al.* 2013; Hamouda *et al.* 2016; Lim and Lee 2016).

**Table 4-3:** Kruskal-Wallis and Dunn's Multiple Comparison Tests for the 9-hour cured Acrylic Partial Denture Bases

| **Kruskal-Wallis Test** | | |
|---|---|---|
| **P value** | 0.7727 | |
| **Exact or approximate P value?** | Gaussian Approximation | |
| **P value summary** | ns | |
| **Do the medians vary significantly (p < 0.05)** | No | |
| **Number of groups** | 4 | |
| **Kruskal-Wallis statistic** | 1.118 | |
| **Dunn's Multiple Comparison Test** | **Difference in rank sum** | **Significant p < 0.05** |
| **Incisal vs Midline** | -2.500 | No |
| **Incisal vs 16** | -2.000 | No |
| **Incisal vs 26** | 0.9000 | No |
| **Midline vs 16** | 0.5000 | No |
| **Midline vs 26** | 3.400 | No |
| **16 vs 26** | 2.900 | No |

**Table 4-4:** The mean values of deformation of Acrylic Partial Denture Bases (1½-hour cure)

| Storage Intervals (day/s) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 1 | 0.2286 | 0.2605 | 0.2203 | 0.2235 |
| 2 | 0.2317 | 0.2694 | 0.2377 | 0.2408 |
| 7 | 0.2884 | 0.3433 | 0.2891 | 0.2900 |
| 14 | 0.2920 | 0.3549 | 0.3073 | 0.3193 |
| 21 | 0.3092 | 0.3561 | 0.3251 | 0.3213 |
| 28 | 0.3204 | 0.3799 | 0.3397 | 0.3434 |

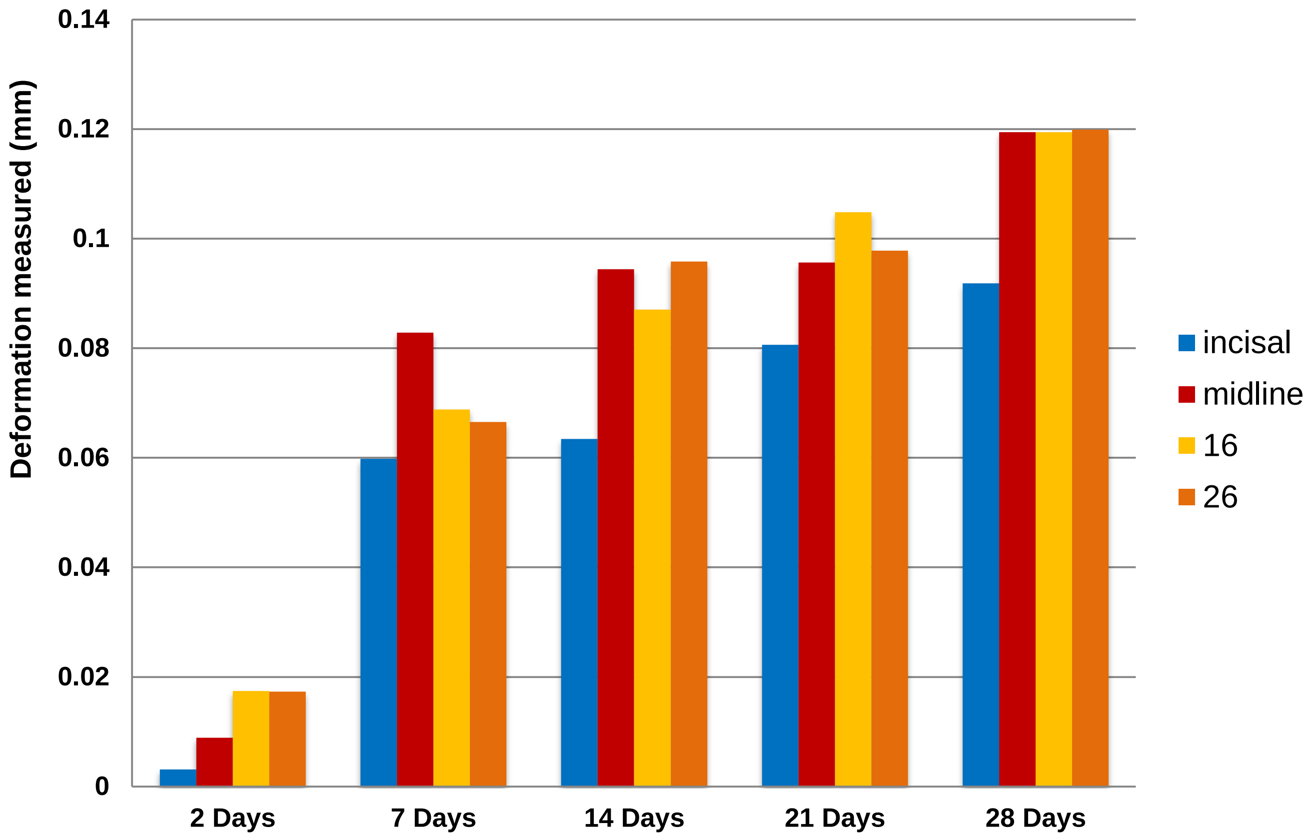


**Figure 4-2:** Trends in Dimensional Deformation of Acrylic Partial Denture Bases Cured for 1½-hour and stored in an incubator over 28 days

**Table 4-5:** Deformation of Acrylic Partial Denture bases (1½-hour cure) measured from immediate fabrication to each storage interval

| Storage Intervals (Days) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 2 | 0.0031 | 0.0089 | 0.0174 | 0.0173 |
| 7 | 0.0598 | 0.0828 | 0.0688 | 0.0665 |
| 14 | 0.0634 | 0.0944 | 0.0870 | 0.0958 |
| 21 | 0.0806 | 0.0956 | 0.1048 | 0.0978 |
| 28 | 0.0918 | 0.1194 | 0.1194 | 0.1199 |
| **Deformation Measured** | **0.05974** | **0.08022** | **0.07948** | **0.07946** |

In addition, the incomplete polymerisation of the 1½-hour curing cycle could contribute to the dimensional deformation of APD bases. This supports the argument of Miessi *et al.* (2008). They argued that the loss of water and incomplete polymerisation during the short curing cycle contributes to the dimensional changes of acrylic dentures. Notwithstanding this Kasina *et al.* (2013) and Savabi *et al.* (2015) reported that rapidly heating dentures at temperatures higher than 74ºC causes dimensional deformation due to the volatilisation of the monomer, which is termed as gaseous porosity. The clinical implication is that this weakens acrylic dentures due to an accumulation of internal stresses. Despite the results in Table 4-6 revealing no significant differences ($p>0.05$), a noteworthy point is that deformation of the APD bases in the incisal, midline and first molar (16 and 26) areas increased over the 28-day storage period (Figure 4-2).

**Table 4-6:** Kruskal-Wallis and Dunn's Multiple Comparison Tests for the 1½-hour cured Acrylic Partial Denture Bases

| **Kruskal-Wallis Test** | | |
|---|---|---|
| **P value** | 0.4015 | |
| **Exact or approximate P value?** | Gaussian Approximation | |
| **P value summary** | n | |
| **Do the medians vary significantly (p < 0.05)** | No | |
| **Number of groups** | 4 | |
| **Kruskal-Wallis statistic** | 2.936 | |
| **Dunn's Multiple Comparison Test** | **Difference in rank sum** | **Significant p < 0.05** |
| **Incisal vs Midline** | -4.900 | No |
| **Incisal vs 16** | -5.100 | No |
| **Incisal vs 26** | -5.600 | No |
| **Midline vs 16** | -0.2000 | No |
| **Midline vs 26** | -0.7000 | No |
| **16 vs 26** | -0.5000 | No |

### 4.3 The Dimensional Stability of Acrylic Partial Denture Bases Cured for 9-hours and Stored in Water for 28 Days

Table 4-7 and Figure 4-3 present the mean values of dimensional deformation measured at the incisal, midline, and first molar (16 and 26) areas of the ten acrylic denture bases, which were cured for 9-hours and stored in water for 28 days. Table 4-8 shows the differences in the fit of acrylic denture bases measured from the point of immediate fabrication *(day 1)* to each storage interval at 2, 7, 14, 21 and 28 days. Although the results in Table 4-9 revealed no significant differences ($p$>0.05), the dimensional deformation of the acrylic denture bases in the incisal, midline and first molar (16 and 26) areas increased over 28 days (Figure 4-3). The highest dimensional deformation measured was in the incisal region (0.06260mm), followed by the deepest part of the midline posteriorly (0.03908mm). Resonating with Abby *et al.* (2011), this is attributed by the different angulations of the anterior region of the hard palate, specifically between the incisive papilla and the mid-palate. Significantly, and as revealed by Consani *et al.* (2011), when dentures are stored in water at 37°C for 24 weeks there is approximately -7.0% and -1.1% dimensional deformation in the incisor and molar regions.

**Table 4-7:** The mean values of deformation of Acrylic Partial Denture Base Stored in Water

| Storage Intervals (day/s) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 1 | 0.2474 | 0.2924 | 0.2227 | 0.2645 |
| 2 | 0.2749 | 0.2928 | 0.2285 | 0.2687 |
| 7 | 0.2775 | 0.3106 | 0.2438 | 0.2689 |
| 14 | 0.2751 | 0.3280 | 0.2649 | 0.2768 |
| 21 | 0.3731 | 0.3494 | 0.2666 | 0.2925 |
| 28 | 0.3494 | 0.3766 | 0.2962 | 0.3118 |

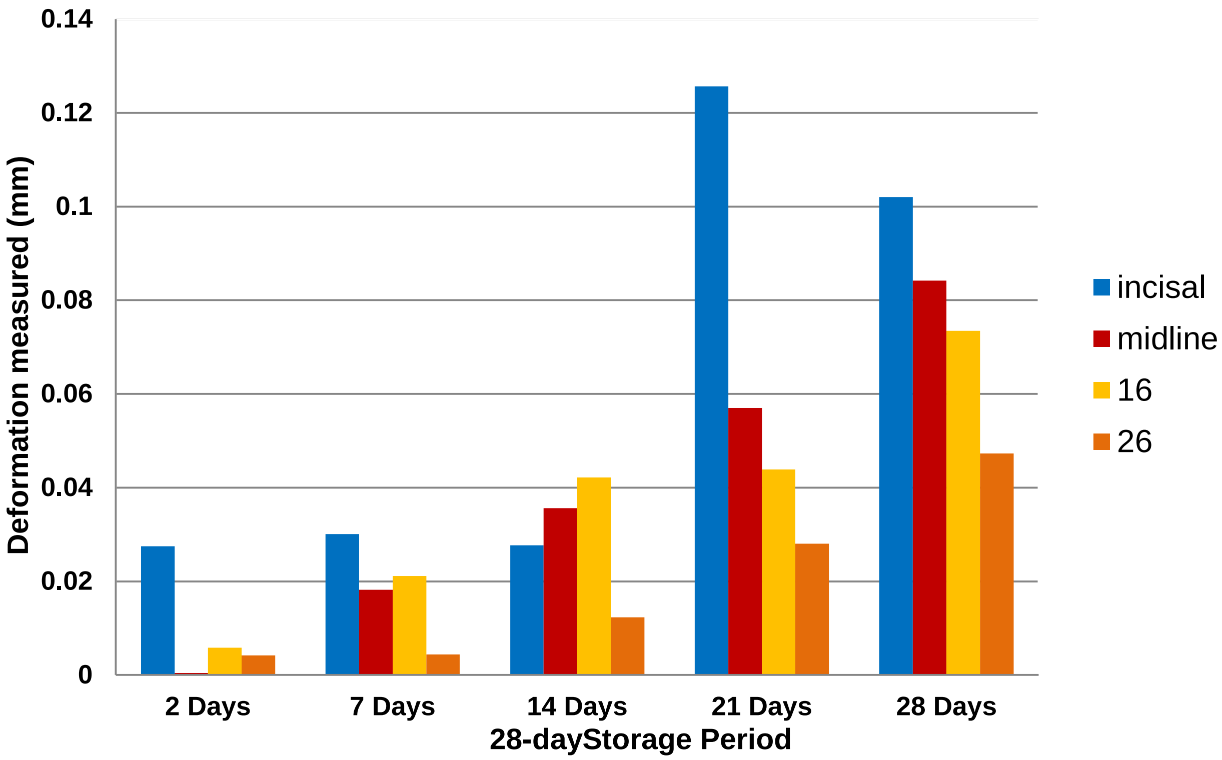


**Figure 4-3:** Trends in Dimensional Deformation of Acrylic Partial Denture Bases Cured for 9-hours and Stored in Water for 28 Days

**Table 4-8:** Deformation of Acrylic Partial Denture Bases (stored in water) measured from immediate fabrication to each storage interval

| Storage Intervals (days) | Reference Areas | | | |
|---|---|---|---|---|
| | Incisal (mm) | Midline (mm) | 16 (mm) | 26 (mm) |
| 2 | 0.0275 | 0.0004 | 0.0058 | 0.0042 |
| 7 | 0.0301 | 0.0182 | 0.0211 | 0.0044 |
| 14 | 0.0277 | 0.0356 | 0.0422 | 0.0123 |
| 21 | 0.1257 | 0.0570 | 0.0439 | 0.0280 |
| 28 | 0.1020 | 0.0842 | 0.0735 | 0.0473 |
| **Deformation Measured** | **0.06260** | **0.03908** | **0.03730** | **0.01924** |

**Table 4-9:** Kruskal-Wallis and Dunn's Multiple Comparison Tests for 9-hour cured Acrylic Partial Denture Bases stored in water

| Kruskal-Wallis Test | | |
|---|---|---|
| **P value** | 0.3934 | |
| **Exact or approximate P value?** | Gaussian Approximation | |
| **P value summary** | ns | |
| **Do the medians vary significantly (p < 0.05)** | No | |
| **Number of groups** | 4 | |
| **Kruskal-Wallis statistic** | 2.989 | |
| **Dunn's Multiple Comparison Test** | **Difference in rank sum** | **Significant p < 0.05** |
| **Incisal vs Midline** | 2.800 | No |
| **Incisal vs 16** | 2.400 | No |
| **Incisal vs 26** | 6.400 | No |
| **Midline vs 16** | -0.4000 | No |
| **Midline vs 26** | 3.600 | No |
| **16 vs 26** | 4.000 | No |

Overall, and in view of the results in Tables 4-3, 4-6 and 4-9, the alternate hypothesis ($H_1$) that is there is a significant relationship between the storage media and the dimensional stability of acrylic partial dentures was therefore rejected.

## 4.4 Comparing and Evaluating the Degree of Dimensional Deformation of the Acrylic Partial Denture Bases across all Sample Groups

### *4.4.1 Incisal Area of the Acrylic Partial Denture Base*

As previously mentioned in Section 3.5 of Chapter 3, a slope test (Graph Pad® Prism - Version 5) was used to compare and evaluate the results of dry-stored dehydrated *(Objectives 1 and 2)* and hydrated *(Objective 3)* acrylic partial denture bases. As seen in Table 4-10, the slope test results of the incisal area of the hydrated *(28 days)* APD bases revealed a low **r²** value. It must be noted that the **r²** value is a fraction between 0.0 and 1.0. An **r²** value of 0.0 indicates that there is no linear relationship between the independent variable and the dependant variable.

The higher the **r²** value the better the regression model fits the data. The **r²** value also indicates the degree of variation that can be explained in the independent variable *(storage period of the acrylic partial denture base)* when changes are made to the dependent variable *(fit of the acrylic partial denture base)*. In contrast to the low **r²** value of the hydrated APD bases, the slope test results of the incisal region of the dry-stored APD bases revealed high **r²** results of 0.9646 (9-hour cure) and 0.8385 (1½-hour cure).

**Table 4-10:** Slope test results of Acrylic Partial Denture Bases in the incisal area

| Incisal Area | | | |
|---|---|---|---|
| **Slope Test *(Goodness of Fit)*** | **Hydrated *(Control)*** | **Dry-stored *(9-Hour Cure)*** | **Dry-stored *(1½-hour Cure)*** |
| **r²** | 0.001452 | 0.9646 | 0.8385 |
| **P value** | 0.9515 | 0.0029 | 0.0290 |
| **Deviation from zero** | Not Significant | Significant | Significant |

Moreover, the slope test also indicates that the slopes for the dehydrated APD bases were significantly different ($p<0.05$). There were no significant differences ($p>0.05$) for the hydrated APD bases. This is further supported by Figure 4-4, which is a time series plot of the measure of deformation from day 1; that is, immediately after fabrication to each storage interval.

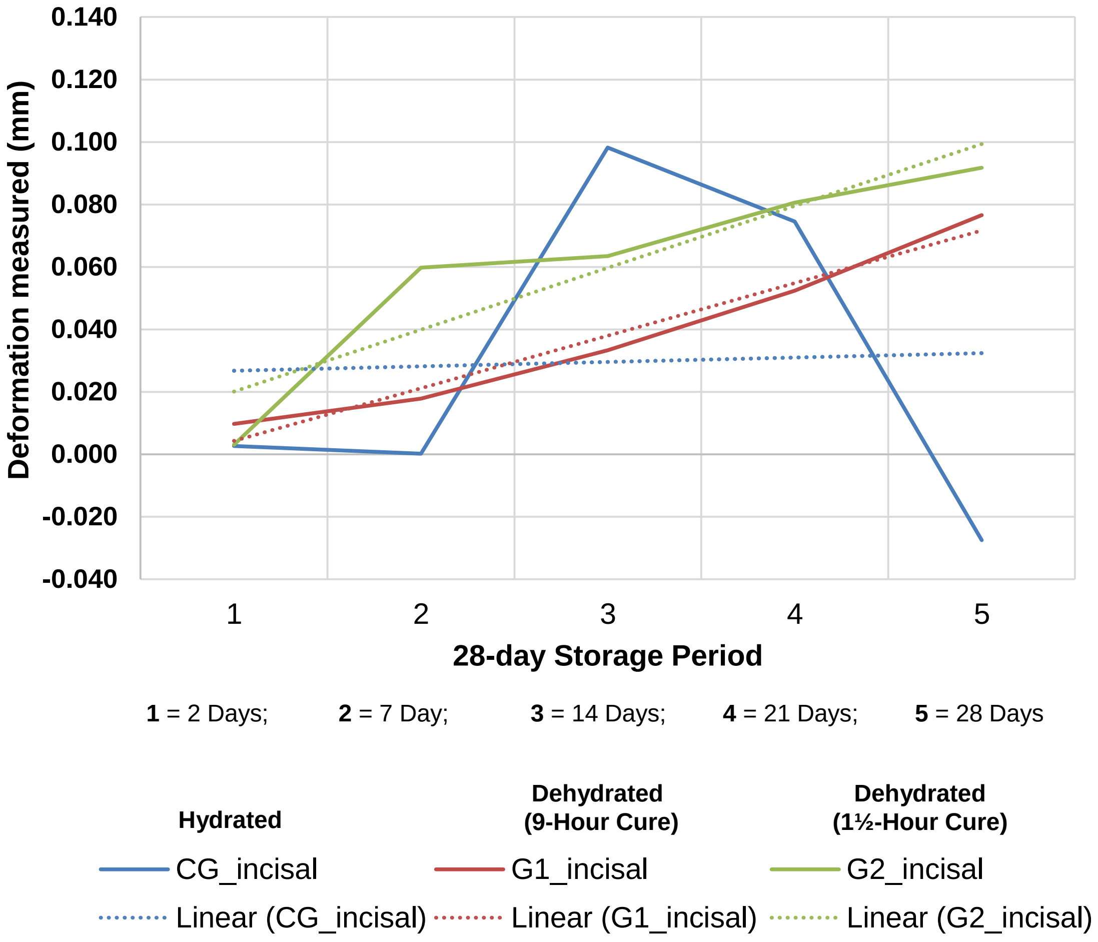


**Figure 4-4:** Deformation of Acrylic Partial Denture bases in the Incisal area

As illustrated in Figure 4-4, the slope pattern of the hydrated APD bases increases from day two to day fourteen. Subsequently the slope pattern decreases from day fourteen to day 28. The irregular slope pattern could be attributed by the affinity of APD bases absorbing water and subsequently expanding. Within the context of this study, and as previously shown in Figure 2-5 in Section 2.3 of Chapter 2, expansion is the measure of a decrease in the gap *(mm)* between the APD base and maxillary cast. Conversely, contraction is the measure of an increase in the gap *(mm)* between the APD base and maxillary cast. It can therefore be inferred that expansion of the APD bases occurred from day fourteen to day 28. This is similar to the work conducted by Rimple *et al.* 2011 and Hamouda 2016, who showed that the highest expansion of complete dentures stored in water occurred in the first month of the three-month storage period. The F-test used to determine if the slopes were equal showed no significant difference (*p*=0.51). In addition, the F-test for elevation testing[3] ($p$<0.05) revealed no significant differences (*p*=0.42). Given that the y intercepts in the elevation test were equal, it can be gathered that the different manufacturing processes (long and short curing cycles) and method of storage (hydrated and dehydrated) does not affect the fit of the APD base, particularly in the incisal area.

*4.4.2 Deepest part of the midline posteriorly*

As illustrated in Table 4-11, the slope test results of the deepest part of the midline area of APD bases posteriorly revealed high **$r^2$** results, namely, 0.9919 (hydrated 9-hour cure), 0.6852 (dehydrated 9-hour cure) and 0.7730 (dehydrated 1½-hour cure). There were significant differences in the hydrated 9-hour cure and the dehydrated 1½-hour cure ($p$<0.05). Figure 4-5 further supports this.

**Table 4-11:** Slope test results of Acrylic Partial Denture bases for the deepest part of the midline area posteriorly

| Midline Area Posteriorly | | | |
|---|---|---|---|
| **Slope Test *(Goodness of Fit)*** | **Hydrated *(Control)*** | **Dry-stored *(9-Hour Cure)*** | **Dry-stored *(1½- Hour Cure)*** |
| **$r^2$** | 0.9919 | 0.6852 | 0.7730 |
| **P value** | 0.0003 | 0.0836 | 0.0495 |
| **Deviation from zero** | Significant | Not Significant | Significant |

There is a positive slope pattern across all three groups in Figure 4-5. The slope pattern for the dehydrated 1½-hour cured acrylic partial denture bases were higher

[3] Generally done for regression lines that show no significant differences in the slopes.

than the hydrated and dehydrated 9-hour cured acrylic partial denture bases. This is consistent with the work of El Sharkawi *et al.* (2017) and Babu *et al*. (2016). The authors reported that using long curing cycle facilitates improved dimensional stability of acrylic denture bases. They further elaborated that in contrast to the short curing cycle, long curing processes reduce the adverse effects caused by an uncontrolled rise in temperature, boiling of monomer, denture base porosity, and associated polymerisation shrinkage.

Overall the F-test used to determine if the slopes were equal revealed no significant difference ($p$=0.15). The F-test for elevation testing showed significant differences across the three groups ($p$=0.00). A significant difference in elevation (y intercepts) indicates that deformation across the three groups are similar and increased over time.

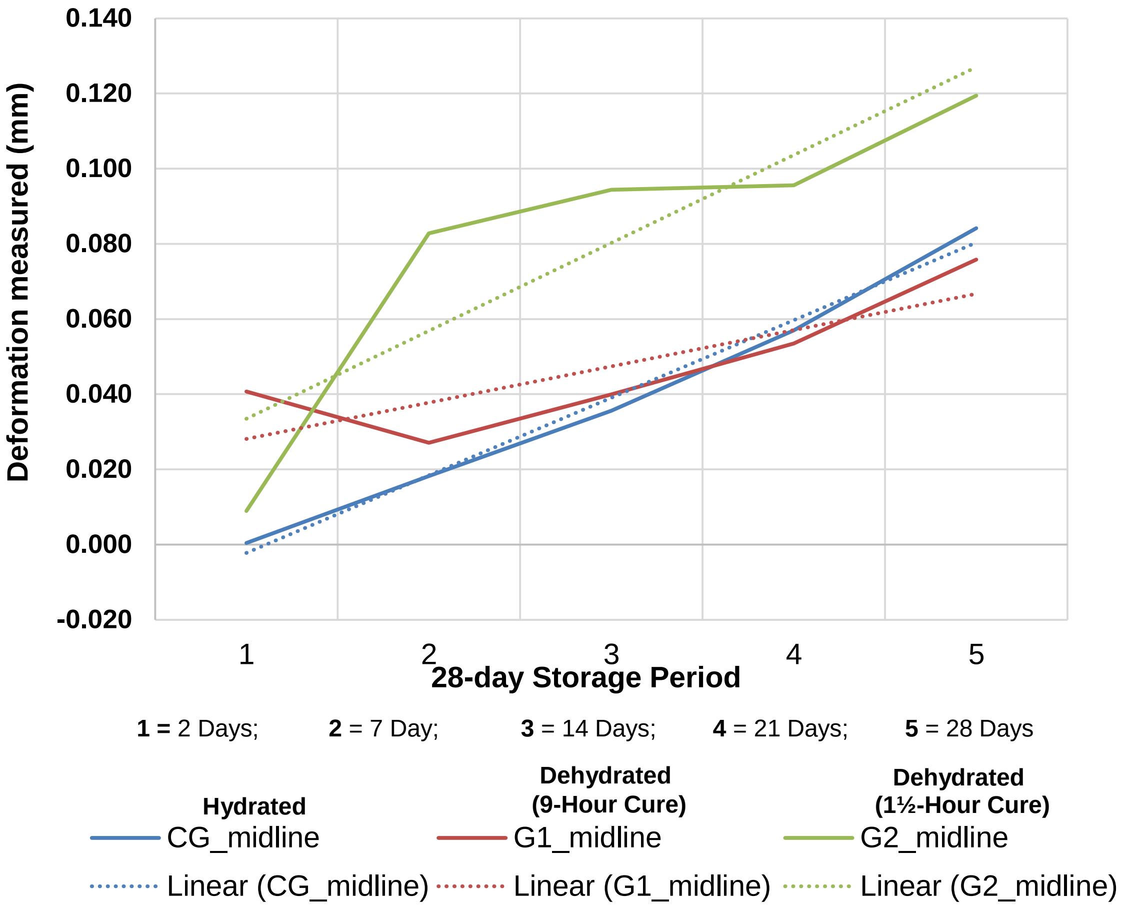


**Figure 4-5:** Deformation of Acrylic Partial Denture bases for the deepest part of the midline area posteriorly

*4.4.3 Area of the First Molar (16)*

As shown in Table 4-12 the slope test results of the APD bases in the first molar area (16) revealed high **$r^2$** values of 0.9507 (hydrated 9-hour cure), 0.9654 (dehydrated 9-hour cure) and 0.9167 (dehydrated 1½-hour cure). As shown in Figure 4-6, the slope test results further indicated that the slopes for all three groups were significantly different ($p<0.05$).

**Table 4-12:** Slope test results of Acrylic Partial Denture bases in the first molar (16) area

| First Molar (16) Area | | | |
|---|---|---|---|
| **Slope Test *(Goodness of Fit)*** | **Hydrated *(Control)*** | **Dry-stored *(9-Hour Cure)*** | **Dry-stored *(1½- Hour Cure)*** |
| **$r^2$** | 0.9507 | 0.9654 | 0.9167 |
| **P value** | 0.0047 | 0.0028 | 0.0105 |
| **Deviation from zero** | Significant | Significant | Significant |

The slope pattern for the dehydrated (1½-hour cure) APD bases is higher than the hydrated and dehydrated (9-hour cure) APD bases. The incomplete polymerisation cycle can be a contributing factor as to why the dehydrated (1½-hour cure) APDs experienced the most amount of deformation compared with the hydrated and dehydrated (9-hour cure) APD bases. The slope pattern for the hydrated 9-hour cured APD bases is the lowest from the three groups. The above results support the recent work of Raman (2017) that deformation of dentures occurs in the first month of storage and gradually decreases at the end of the third month of storage. The F-test used to determine if the slopes were equal showed no significant difference ($p$=0.16). The F-test for elevation testing revealed significant differences across the three groups ($p$=0.00). In view of the results, the alternate hypothesis ($H_1$) that is there is a significant relationship between the storage media and the dimensional stability of acrylic partial dentures was therefore accepted.

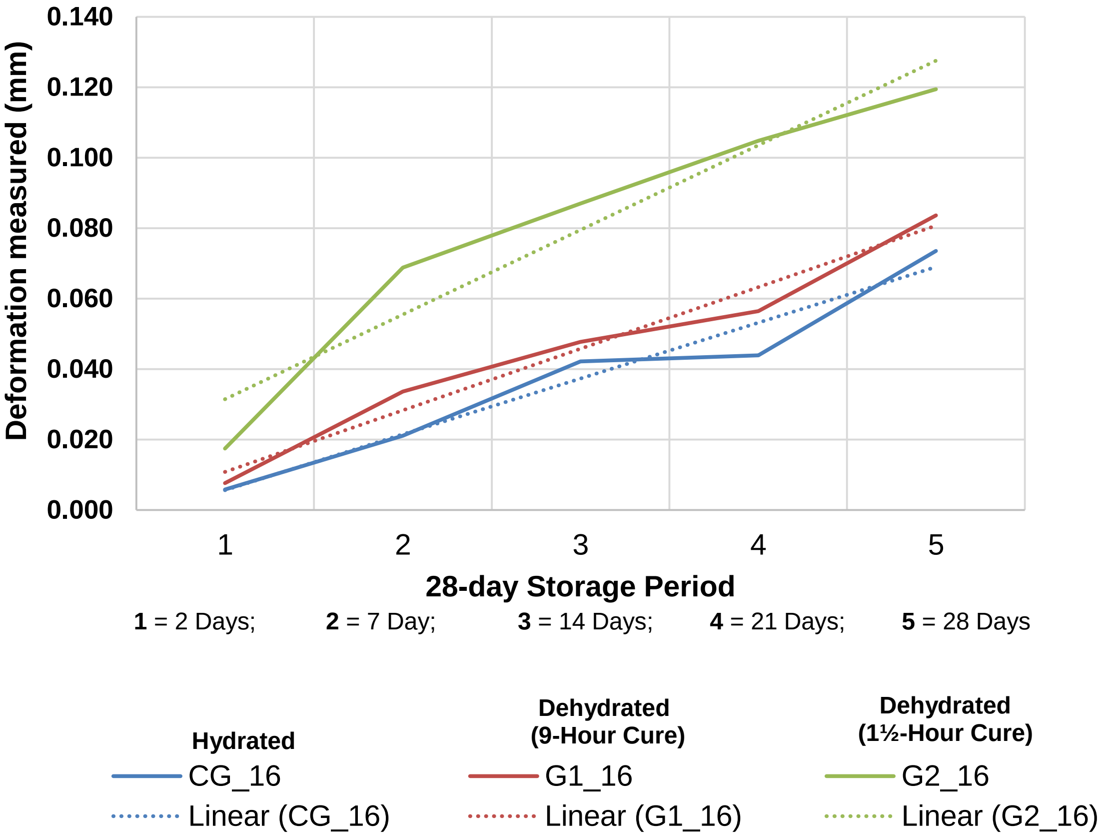


**Figure 4-6:** Deformation of Acrylic Partial Denture bases in the first molar (16) area

*4.4.4 Area of the First Molar (26)*

As illustrated in Table 4-12, the slope test results of the APD bases in the first molar area (26) revealed high **r²** values of 0.8871 (hydrated 9-hour cure), 0.9312 (dehydrated 9 hour cure) and 0.8891 (dehydrated 1½-hour cure). Moreover, the slope test revealed significant differences across all sample groups. This is further supported by Figure 4-7, which shows a positive linear relationship for the hydrated, dehydrated (9-hour cure) and dehydrated (1½-hour cure) APD bases. The slope pattern for the dehydrated (1½-hour cure) APD base is higher than the hydrated and dehydrated (9-hour cure) APD bases.

**Table 4-13:** Slope test results of Acrylic Partial Denture bases in the first molar (26) area

| First Molar (26) Area | | | |
|---|---|---|---|
| **Slope Test *(Goodness of Fit)*** | **Hydrated *(Control)*** | **Dry-stored *(9-Hour Cure)*** | **Dry-stored *(1½- Hour Cure)*** |
| **Y-intercept when X=0.0** | -0.0140 ± 0.007514 | -0.003600 ± 0.006454 | 0.008500 ± 0.01602 |
| **$r^2$** | 0.8871 | 0.9312 | 0.8891 |
| **P value** | 0.0167 | 0.0078 | 0.0162 |
| **Deviation from zero** | Significant | Significant | Significant |

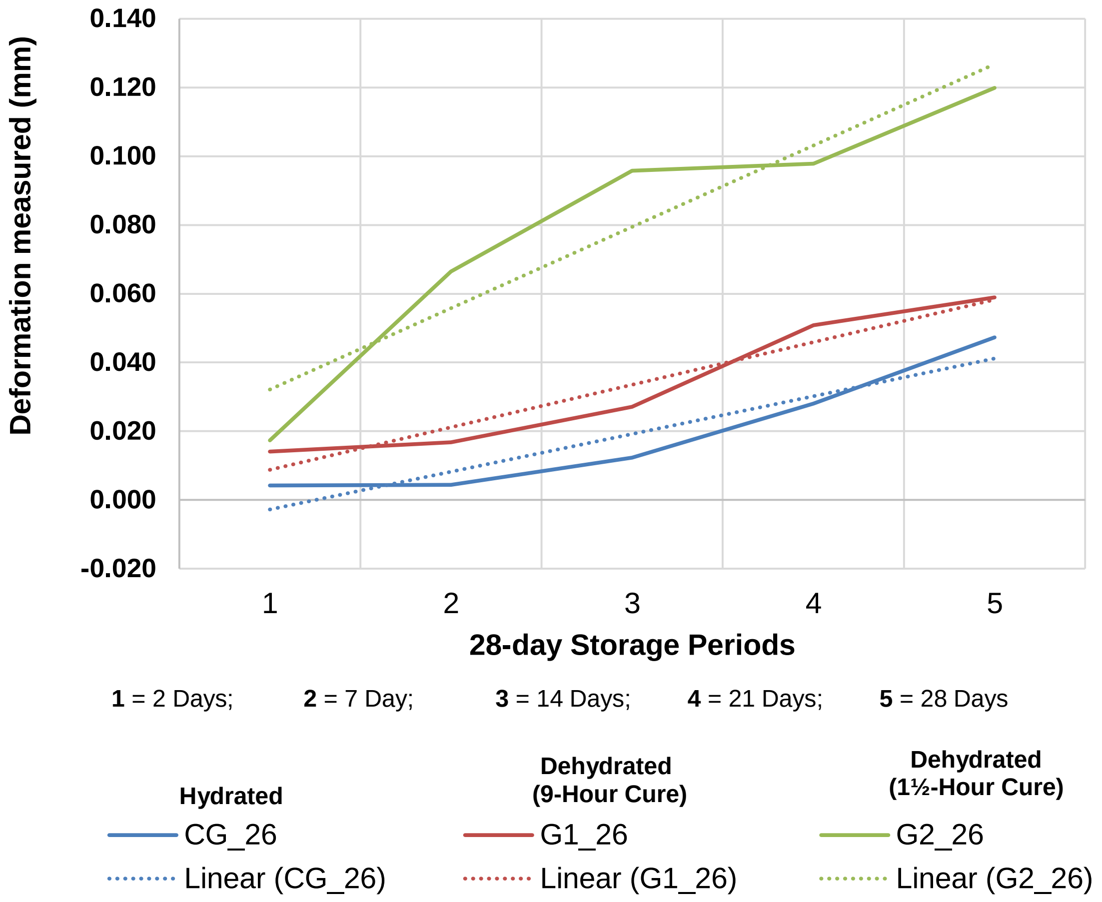


**Figure 4-7:** Deformation of Acrylic Partial Denture bases in the first molar (26) area

The F-test used to determine if the slopes were equal showed significant differences between the slopes (*p*=0.04). As outlined in Table 4-13 the dehydrated (1½-hour cure) APD bases had the highest elevation (0.008500 ± 0.01602). In contrast the hydrated APD bases had the lowest elevation (-0.0140 ± 0.007514). It can therefore be inferred that storing APD bases in water reduces the degree of deformation. These results are consistent with the findings by Consani *et al.* (2011). They demonstrated that over a 24-week period complete dentures stored at room temperature had higher deformation than dentures stored in water. Lim and Lee (2016) therefore advised storing dentures in water when not worn intraorally as it reduces distortion and shrinkage. A critical point that deserves to be mentioned is that the increased curvature of the tissue on the hard palate could have contributed to the regression slopes of the first molar (26) area being significantly different. In corroboration with Abby *et al.* (2013), increased deformation on the right side of the denture base was evident as opposed to the left. In view of the aforementioned results, the alternate hypothesis ($H_1$) that is there is a significant relationship between the storage media and the dimensional stability of acrylic partial dentures was therefore accepted.

### *4.4.5 Summary of the Results*

Although there were no significant differences for objectives one, two and three, the slope test revealed significant differences for objective four (Table 4-13). A noteworthy point is that the 9-hour dehydrated cured APD bases showed visible changes in dimensional stability (Figure 4-1). This study supports the work of Miessi *et al.* (2008) as the loss of water and incomplete polymerisation affects the dimensional fit of APD bases, especially when the dentures are dry stored. In contrast to Lim and Lee (2016), who demonstrated that the degree of deformation reduced over a longer dry storage period (over a month), the results of this study showed that the highest deformation occurred on day 28 of the storage period. Although there were no significant differences across the sample groups, the deformation across all four reference areas were higher for the dehydrated (1½-hour cure) APD bases than the hydrated and dehydrated (9-hour cure) APD bases. The hydrated (9-hour cure) APD bases had the lowest deformation. This aligns with Anusavice, Shen and Rawls (2013), who recommended using a 9-hour curing cycle to reduce polymerisation shrinkage and to achieve dimensionally stable denture bases. Several authors (Ristic and Carr 1987; Consani *et al.* 2002;

Consani *et al.* 2003; Kobayashi, Komiyama and Kawara 2004) further recommended storing dentures in water for at least 24 hours post-manufacture, in order to compensate for polymerisation shrinkage.

As seen in Table 4-10, the results of the slope test for the acrylic partial denture bases revealed no significant difference incisally, however there were significant differences posteriorly. This is consistent with Consani *et al*. (2003) and Arora *et al.* (2011), who showed that shrinkage in maxillary complete dentures occurs in the posterior palatal area. More recently Lim and Lee (2016) observed significant linear bilateral posterior buccal flange deformation of complete dentures during dry-storage. The posterior deformation of an 'n' shape (See Chapter 1, Section 1.3) APD is more likely to be higher than a 'w' shape complete denture, which gains additional support by the buccal flanges. The results of the study aligns with the clinical findings of several studies (Darvell and Clark 2000; Nallaswamy 2007; Raman 2017; Georgieva *et al.* 2016). In particular, dimensionally unstable dentures increases food impaction between the ill-fitting denture base and supporting tissues, and causes gum stripping and sore spots on the oral mucosa. Dental clinicians and denture wearers should therefore not dry store acrylic dentures. The next chapter will provide the conclusions drawn from this study. This will include limitations and directions for further research.

# Chapter 5 – Conclusion and Recommendation

The focus of this study was to investigate the extent of dimensional instability of acrylic partial denture bases by temperature and humidity. An experimental research design within a quantitative framework was used. There were three sample groups, namely: the hydrated 9-hour cure *(Control),* dehydrated 9-hour cure *(Group 1)* and dehydrated 1½-hour cure *(Group 2)*. Each sample group had ten APD base specimens. In terms of storage periods, sample groups one and two were stored in a custom-made incubator for 28 days with the temperature and humidity levels regulated at 21ºC and 40%, respectively. The control sample group was stored in a water bath for 28 days. The dimensional fits of the APD bases were measured periodically in order to ascertain the degree of deformation (mm), which was subsequently compared and evaluated across all sample groups. This chapter makes recommendations on the fabrication and storage method to be used in the dental laboratory, and concludes by proposing future directions for research.

Although there were no significant differences in the degree of deformation across the three sample groups, there was evidence that the posterior areas of the APD bases in the first molar areas contracted due to an increase in deformation. In particular, the slope test results revealed that the APD bases which were stored in water (control group) had the lowest deformation patterns. In contrast, the slope patterns of the dehydrated APD bases had higher deformation patterns. The results of this study further showed that the degree of deformation increased over time. Notably this study conclusively showed that curing APDs for nine hours increases the dimensional fit, which is further enhanced if kept hydrated on storage.

In summary, the aim of the study was to investigate the effect of dehydration on the dimensional stability of acrylic partial dentures. The results for objectives one, two and three *(Section 1.5, Objectives 1.5.1; 1.5.2; 1.5.3)* revealed no significant differences. This suggests that the curing and storage methods had no significant influence on the extent of deformation of APD bases. Equally important, the results for objective four *(Section 1.5, Objective 1.5.4)* revealed that the rehydrated APD bases *(control group)* had the lowest deformation patterns. The slope patterns of the dehydrated APD bases by contrast had higher deformation patterns. It can therefore be concluded that the hypothesis, which stated that there is a significant relationship between the storage media and the dimensional stability of acrylic partial denture bases was accepted.

Furthermore, given the location of the reference areas and the different time intervals to capture measurements, the silicone wafer method was deemed appropriate. Distortion of the silicon wafer can occur, however, if it is not carefully removed from the stone model. Notwithstanding this, the varying skills among dental technicians in terms of controlling the homogeneity of the silicone mixture and its removal from the model could further contribute to the distortion of the set silicone. Hence other less-sensitive techniques to measure the extent of denture deformation, such as 3D scanners and surface matching software, are recommended as alternative methods to the silicone wafer measuring procedure. Additionally, and while using the silicon wafer method to measure the degree of deformation, the differences in temperature and humidity levels between the environment and the incubator could affect the dimensional fits of the APD denture bases. A larger climate control room in which to conduct the experiment is therefore recommended to overcome this limitation.

An area for further research would be to determine the dry-stored parameters, which relates to the period at which the deformation of APD bases decreases. This information could provide useful guidelines to both clinicians and patients in reducing deformation on storage, thereby improving denture care practices.

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# Appendices

## Appendix 1a: Thermo-Hygrometer certificate of compliance

**TCT**

***Certificate of Compliance***

| | | |
|---|---|---|
| **Certificate No.** | : | TCT151014R001C |
| **Applicant** | : | Shenzhen Flus Technology Co., Ltd |
| **Address** | : | 3rd Floor, Lantian Building, Fountain Science Park, Pingan Road, Pinghu Town, Longgang District, Shenzhen, China |
| **Manufacturer** | : | Shenzhen Flus Technology Co., Ltd |
| **Address** | : | 3rd Floor, Lantian Building, Fountain Science Park, Pingan Road, Pinghu Town, Longgang District, Shenzhen, China |
| **Product** | : | Thermo-Hygrometer |
| **Model No.** | : | FL-201, FL-201W |
| **Trade mark** | : | N/A |

The above products have been tested by us with listed standards and found in compliance with the directive RoHS 2011/65/EU. It is possible to use RoHS marking to demonstrate the compliance with this RoHS.

| Test standards: | Report(s) Number | Issued By | Issued Date |
|---|---|---|---|
| IEC 62321:2008<br>IEC 62321:2013 | TCT151014R001 | TCT | Oct. 16, 2015 |

The statement is based on a single evaluation of one sample of above mentioned products. It does not imply an assessment of the whole production and does not permit the use of the test lab logo.

[redacted]

Tomsin/Senior Engineer

Oct. 16, 2015

**RoHS**

SHENZHEN TCT TESTING TECHNOLOGY CO., LTD — TCT

Shenzhen TCT Testing Technology Co.,Ltd.

Hotline: 400-6611-140 Tel: 86-755-27673339 Fax: 86-755-27673332 Http://www.tct-lab.com

## Appendix 1b: Thermo-Hygrometer certificate of compliance

# TCT

## *Certificate of Compliance*

| | | |
|---|---|---|
| **Certificate No.** | : | TCT151014E001C |
| **Applicant** | : | Shenzhen Flus Technology Co., Ltd |
| **Address** | : | 3rd Floor, Lantian Building, Fountain Science Park, Pingan Road, Pinghu Town, Longgang District, Shenzhen, China |
| **Manufacturer** | : | Shenzhen Flus Technology Co., Ltd |
| **Address** | : | 3rd Floor, Lantian Building, Fountain Science Park, Pingan Road, Pinghu Town, Longgang District, Shenzhen, China |
| **Product** | : | Thermo-Hygrometer |
| **Model No.** | : | FL-201, FL-201W |
| **Trade mark** | : | N/A |

The above products have been tested by us with listed standards and found in compliance with the council EMC 2004/108/EC. It is possible to use CE marking to demonstrate the compliance with this EMC.

| Test standards: | Report(s) Number | Issued By | Issued Date |
|---|---|---|---|
| EN 61326-1:2013<br>EN 61000-3-2:2014<br>EN 61000-3-3:2013<br>EN 61326-2-2:2013 | TCT151014E001 | TCT | Oct. 15, 2015 |

The statement is based on a single evaluation of one sample of above mentioned products. It does not imply an assessment of the whole production and does not permit the use of the test lab logo.

[redacted]

Tomsin/Senior Engineer

Oct. 15, 2015

SHENZHEN TCT TESTING TECHNOLOGY CO., LTD

TCT

Shenzhen TCT Testing Technology Co.,Ltd.

Hotline: 400-6611-140 Tel: 86-755-27673339 Fax: 86-755-27673332 Http://www.tct-lab.com

# Appendix 2a: Micrometer calibration report

pc•dmis

| PART NAME : | MITUTOYO MICROMETER | | 25/10/2016 | 10:17 |
|---|---|---|---|---|
| REV NUMBER : | | SER NUMBER : 293-330 | STATS COUNT : | 1 |

| ↔ | MM | DIST2 - PNT8 TO PNT9 | | | | |
|---|---|---|---|---|---|---|
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL |
| M | 10.000 | 0.100 | 0.100 | 9.991 | -0.009 | 0.000 |

| ↔ | MM | DIST3 - PNT4 TO PNT5 | | | | |
|---|---|---|---|---|---|---|
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL |
| M | 17.000 | 0.100 | 0.100 | 16.994 | -0.006 | 0.000 |

| ↔ | MM | DIST4 - PNT6 TO PNT7 | | | | |
|---|---|---|---|---|---|---|
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL |
| M | 25.000 | 0.100 | 0.100 | 24.997 | -0.003 | 0.000 |

# Appendix 2b: Calibration certificate: Digital micrometer

DUT DURBAN UNIVERSITY OF TECHNOLOGY — technology innovation AGENCY

**DIGITAL MICROMETER INSPECTION REPORT**

| | | | | | |
|---|---|---|---|---|---|
| ATTENTION | Mohammed Motala | | | REPORT No. | No. 1 |
| SERIAL NUMBER: | 293-330 | CAVITY NUMBER | | CHANGE NOTE NO. | |
| PART NAME | Mitutoyo Digital Micrometer | | | USED ON | |
| DRAWING NO. | | GENERAL TOLERANCES | SEE DRAWING | ENG. LEVEL | |
| REPORT SUPPLIER | Technology Station [DUT] | | | Previous Report No. | |
| REQUESTED BY: | Mohammed Motala | | SAMPLES SUBMITTED 1 | Supplier's Code No. | |
| DEPT. | Dental dept | Timing – Planned Date: | | Date Report Required: | |
| SUBMISSION DATE: | 02/06/2017 | BUYER'S NAME | | | |

| REF | NOMINAL DIMENSION [mm] | TOLERANCE - | TOLERANCE + | TECH. STATION INSPECTION RESULTS | VERIFICATION OF INSPECTION RESULTS | Out of Spec | COMMENTS |
|---|---|---|---|---|---|---|---|
| 01 | 10.00 | 0.01 | 0.01 | 9.991 | | | |
| 02 | 17.00 | 0.01 | 0.01 | 16.994 | | | |
| 03 | 25.00 | 0.01 | 0.01 | 24.997 | | | |
| 04 | | | | | | | |
| 05 | | | | | | | |
| 06 | | | | | | | |
| 07 | | | | | | | |
| 08 | | | | | | | |

IMDS NODE I.D. / CCB — MASS OF PART

STATE ACTUAL MATERIAL USED FOR SAMPLES: [IF NOT AS SPECIFIED BY THE DRAWING] — DATA INPUT CLERK

**PLEASE COMPLETE INSPECTION FROM LEFT TO RIGHT ON DRAWING**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| INSPECTED BY (SUPPLIER) | Technology Station [DUT] | DATE | 25/10/16 | INSPECTED BY | M. Maqashu | DATE | 05/06/17 |

| TO BE COMPLETED BY SUPPLIER | | TO BE COMPLETED BY - Technology Station [DUT] | | | | |
|---|---|---|---|---|---|---|
| Are these samples a first time submission | | DISPOSITION | APP | REJ | SIGNATURE | DATE |
| If no, reflect previous inspection report no. | | DIMENSIONAL | X | | B. Clarke | 05/06/2017 |
| Have samples been made on prod, set up & tooling | | FUNCTIONAL | | | | |
| If no, specify | | COMPONENT ENG. | | | | |
| We hereby certify that we believe the above inspection results to be correct and samples meet SMSA specifications | | OTHER | | | | |
| Signature & Title of Responsible Official — B Clarke | DATE: 05/06/17 | DRG. SPEC TO BE UPDATED | YES | NO | | |

* Original Copy must be returned to Metrology * — Doc No.

## Appendix 3: Thermo-hygrometer and mercury thermometer temperature report

| Date and time | Temperature (°C) | | Humidity (%) | | Sign | Sign |
|---|---|---|---|---|---|---|
| | Thermo-Hygrometer | Mercury Thermometer | Maximum | Minimum | | |
| **31-10-16** | | | | | | |
| 08h45 | 21.1 | 21 | 40 | 39.5 | [redacted] | |
| 15h45 | 20.9 | 21 | 40 | 39.6 | [redacted] | |
| **01-11-16** | | | | | [redacted] | |
| 08h45 | 21.1 | 21 | 40 | 39.5 | [redacted] | |
| 15h45 | 20.9 | 21 | 40 | 39 | [redacted] | |
| **06-11-16** | | | | | [redacted] | |
| 08h45 | 20.9 | 21 | 40 | 38.9 | [redacted] | |
| 15h45 | 21.1 | 21 | 40 | 39 | [redacted] | |
| **13-11-16** | | | | | [redacted] | |
| 08h45 | 20.9 | 21 | 40 | 39 | [redacted] | |
| 15h45 | 21.1 | 21 | 40 | 39.5 | [redacted] | |
| **20-11-16** | | | | | [redacted] | |
| 08h45 | 20.9 | 21 | 40 | 39 | [redacted] | |
| 15h45 | 20.9 | 21 | 40 | 39.5 | [redacted] | |
| **27-11-16** | | | | | [redacted] | |
| 08h45 | 21.1 | 21 | 40 | 39.5 | [redacted] | |
| 15h45 | 20.9 | 21 | 40 | 39.6 | [redacted] | |

# Appendix 4: Approval letter

DUT DURBAN UNIVERSITY OF TECHNOLOGY

FACULTY OF HEALTH SCIENCES

10 March, 2016

Student No: 21008270

Mr M Motala
PO Box 192
Ramsgate
4285

Dear Mr Motala

**MASTER OF HEALTH SCIENCES: DENTAL TECHNOLOGY**

I am pleased to advise that:

1. The Research and Higher Degrees Committee approved the following:

 (i) Your research proposal and dissertation title, being:

***The effect of dehydration on the dimensional stability of acrylic partial denture bases.***

**Please note: ANY PROPOSED CHANGES in the DISSERTATION TITLE require the approval of your supervisor and the Faculty Research Committee.**

 **(ii)** Supervisor – **Professor T Puckree**
 **(iii)** Co-Supervisor – **Ms DA Skea**

2. Your request for funding totalling **R 10 000.00** subject to any literature referred to in Section A of the PG 4a form being accessioned by this University, and any equipment purchased shall become the property of the department.

**NOTE: - This funding is not paid directly to you but is controlled by the Faculty Research Officer. Any proposed changes to this funding allocation needs the approval of your supervisor, and Faculty Research Committee**

The University Research Committee has stipulated that:

(a) Ownership of any patent registered in respect of the results of your Master's Degree studies is retained by you as the initiator of the project;

(b) Should you make any Drift from the results of your Master's Degree studies, you will be required to repay pro rata, the **R 10 000.00** investment which the University Research Committee has made in approving your request for funding;

(c) If the Durban University of Technology provided the equipment/materials for the creation of artefacts, this cost would be refunded to the University if such artefacts were sold and

(d) Durban University of Technology is given first refusal in respect of any possible future sale by you of any patent that may be registered in respect of your said project.

(e) All journal articles, referenced in your dissertation, are to accompany your ring-bound copies when submitting for examination purposes.

May I remind you that notwithstanding Rule LX.CM2, if a student fails to obtain the Masters Degree within two years of first registering for the fifth year, re-registration may be denied. The Academic Board may refuse to renew such registration or may impose any conditions it deems fit.

Should you experience any problems relating to your research studies, your supervisor must be informed as soon as possible. If the difficulty persists, you must then approach your Head of Department and thereafter the Dean of the Faculty.

Yours sincerely

[redacted]

**Mr S Reddy**
**FACULTY RESEARCH OFFICER**

[redacted]

**Student's signature in acceptance of the conditions contained herein.**

**10 March 2016**

**Date:**