MECHANICAL AND HANDLING PROPERTIES OF LIGHT – CURED ACRYLIC RESIN CUSTOM TRAY MATERIAL

By

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Light-cured

Dimensional stability

Fracture toughness

User-friendliness

Training

ABSTRACT

Objectives

1) To determine the linear dimensional shrinkage and fracture toughness of light-cured acrylic custom tray materials and compare it to the chemically-cured type.
2) To evaluate the acceptance of light-cured acrylic resin custom trays by undergraduate students.

Methods

Twenty light-cured acrylic specimens (Megatray, Megadent, Radeberg, Germany) with configurations of 2 x 4.2 x 20mm for determining dimensional stability were fabricated using a custom-made perspex template. The template length (20mm) served as the standard to compare dimensional changes. The specimens were measured 3 times using digital calipers, at intervals of 30 min, 1 hr, 24, 36 and 48 hrs following polymerization. The mean, median and interquartile ranges of the average shrinkage were calculated. The extent of shrinkage over time from the standard (20mm) was evaluated using the Wilcoxon Signed Rank test.

For fracture toughness**,** 20 chemically- (Excel special tray material, Wright Health Group, United Kingdom) and light-cured specimens (Megatray, Megadent, Radeberg, Germany) with a 3mm centrally placed notch on one edge were fabricated. A central load was applied to each specimen in a three-point-bending mode at a crosshead speed of 0.5mm/min until it fractured using a universal-testing machine. The force applied to fracture the light- and chemically-cured specimens was compared using the Wilcoxon Ranked Sum Test. The mean, median and standard deviation for fracture toughness were calculated.

Analysis of the individual components of each material in its uncured and cured forms was performed using infra-red spectroscopy.

A cross-sectional study was carried out amongst 4^{th} and 5^{th} year dental students who had clinical and laboratory experience with light- and chemically-cured custom tray materials. A questionnaire, analyzing the acceptance of the light- over the chemically-cured resin, was distributed amongst the students and their opinions were compared.

Results

The medians of the shrinkage in mm were as follows:
At 30min: 0,230; at 1 hr: 0,245; at 24hrs: 0,200; at 36hrs: 0,265 and at 48hrs: 0,280. Shrinkage at the different time intervals were compared to the standard ($p<0.05$). The changes in shrinkage over time were not significantly different ($p>0.05$).

The force needed to fracture the specimens was 3.45- 17.01N for the light-cured and 0 – 2.79N for the chemically-cured specimens. According to the Wilcoxon Sum Rank test, this difference in force between the two materials is significant ($p<0.05$).
The fracture toughness for the light-cured specimen was 21.461 – 105.815 $MPa.m^{0.5}$ and 0 -17.355 $MPa.m^{0.5}$ for the chemically-cured type. This difference was also significant ($p<0.05$).

The range of the wavelengths for each component tested is from 500 – 4000 cm^{-1}.

One hundred and thirty nine students participated in the survey. Seventy seven percent indicated they used the light-cured material most often, 64% indicated it saved time and 62 % indicated that it was easier to handle. Fifty four percent indicated that both types of materials should be used in undergraduate training; 24%

preferred the light-cured, 18% suggested only the light-cured and no one the chemically-cured exclusively. There was a tendency towards the light-cured resin, yet 48% of the 4th and 68% of the 5th year class preferred that the use of both materials be taught.

Conclusions

Custom trays made from light-cured acrylic resin may be used immediately after polymerization contrary to the chemically-cured resin.

Light-cured acrylic resin is stronger than the chemically-cured type.

Most students positively accepted the light-cured resin, but training in the use of both materials was suggested.

DECLARATION

I, Saadika Khan, hereby declare that *Mechanical and handling properties of light-cured acrylic resin as custom tray materials* is my own original work, that I have not previously submitted it in part or in its entirety towards a degree at any other university and that all sources I have used or quoted have been indicated and acknowledged by complete references.

_____

S. B. Khan

_____Day of _____ of 2007

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CHAPTER 1

INTRODUCTION

1.1 Problem statement

Both light-cured (LC) and chemically-cured (CC) acrylic resin custom tray materials are used at the Oral Health Centre, Faculty of Dentistry, University of the Western Cape. At present, the CC acrylic is the standard for formal undergraduate teaching and training. The LC material is not part of routine didactic teaching as little evidence-based scientific information is available with regards to its properties and its usage in the clinical environment. On the other hand, CC acrylic resin custom tray materials have been researched extensively and proven clinically acceptable. But it has certain disadvantages: polymerization shrinkage; vapor emittance; toxicity; residual monomer and adverse tissue reactions and related diseases varying with the extent and time of exposure (Scott *et al*, 2004; Jorge *et al*, 2003; Leggat & Kedjarune, 2003; Hochman & Zalkind, 1997 and Pettersen & Jacobsen, 1991).

Another negative property often associated with the CC material is that of polymerization shrinkage over time and a waiting period between fabrication and use as recommended by researchers (Rueda *et al*, 1996 and Fehling *et al*, 1986).

These negative effects have caused researchers to focus on alternatives and to research for other materials with more advantageous properties: shellac baseplate (Stipho, 1994 & Azouka *et al*, 1993); thermoform (Smith *et al*, 1999; Brown & Kerr, 1998; Jagger & Okdeh, 1995; Breeding *et al*, 1994 and Gordon *et al*, 1990); LC acrylic resin (Ling, 2004; Smith *et al*, 1999; Baker & Frazier, 1999; Brown & Kerr, 1998; Breeding *et al*, 1994 and Wirz *et al*, 1990) and the polycaprolaitone materials (Pilcher & Draughn, 1993).

The statements above were the major reasons why a study of this nature including a survey amongst the dental students was conducted.

An alternative is the LC acrylic resin custom tray materials. Although the LC material is more expensive, it is a clinical impression that the material is user-friendlier by saving time and eliminating the hazardous effects associated with the CC materials. In a training institution where large amounts of laboratory work is generated these are important factors. But it is also perceived that the LC material is more brittle and it seems to fracture more often than its CC counterparts.

As these LC acrylic resin custom tray materials are available and used extensively already in commercial laboratories, the merits of using these materials should be taught in the undergraduate dental curriculum.
Premarket testing and several individual studies to examine the properties of these materials have been done (Scott *et al*, 2004). No studies examining the opinions of users of both these materials at undergraduate level combined with scientific research on some of the properties of the LC materials in one study are available.

1.2 Introduction

The debate surrounding the properties of dental materials started centuries ago and is an ongoing phenomena as new and improved materials appear on the market. The physical, chemical and the handling properties of new materials are scrutinized extensively in premarket testing in laboratories. But surveillance systems need to be available to monitor these materials when used on patients and to provide an evidence-based system. Of special concern is the potential toxicity of materials (Scott *et al*, 2004; Jorge *et al*, 2003; Leggat & Kedjarune, 2003; Hochman & Zalkind, 1997; Pettersen & Jacobsen, 1991; Rajaniemi & Tola, 1985 and Seppäläinen & Rajaniemi, 1984).

The success of complete removable denture treatment depends on the correct clinical and laboratory procedures instituted and taught as part of any dental curriculum

(Anderson *et al*, 1988). An important stage is the making of accurate impressions and the selection of materials used during this procedure (Burns *et al*, 2003; Smith *et al*, 1999; Millstein *et al*, 1998; Rueda *et al*, 1996; Ogden *et al*, 1994; Wirz *et al*, 1990; Gordon *et al*, 1990; Fehling *et al*, 1986 and Mendez, 1985).

Considering the wide variety in shape and size of patients' edentulous arches and comparing it with the range of stock trays available, considerable discrepancies between the denture bearing tissues and the tray may exist, even after stock tray modifications (Smith *et al*, 1999; Millstein *et al*, 1998; Ogden *et al*, 1994 and Mendez, 1985). Researchers have shown that several discrepancies exist on casts made from impressions taken in stock trays (Castellani & Basile, 1997; Rueda *et al*, 1996 and Ogden *et al*, 1994).

The importance of using custom trays has been emphasized in several publications (Burns *et al*, 2003; Hyde & Mc Cord, 1999; Millstein *et al*, 1998; Castellani & Basile, 1997; Ogden *et al*, 1994; Wirz *et al*, 1990; Gordon *et al*, 1990 and Valderhaug & Floystrand, 1984). The custom tray allows an even but thin film of impression material to be used, which largely is responsible for the accuracy of the impression and the resultant casts (Christenson, 1994 cited by Millstein *et al*, 1998; Castellani & Basile, 1997; Rueda *et al*, 1996; Pilcher & Draughn, 1993 and Valderhaug & Floystrand, 1984).

Different materials are available for the construction of custom trays but those with the most suitable chemical and physical properties, best user-friendliness and biocompatibility should be used (Smith *et al*, 1999; Millstein *et al*, 1998; Rueda *et al*, 1996; Ogden *et al*, 1994; Breeding *et al*, 1994; Hitge *et al*, 1991; Gordon *et al*, 1990; Wirz *et al*, 1990 and Fehling *et al*, 1986).

The dimensional stability and accuracy of final impression materials (hydrocolloids and elastomers) have been studied and proven repeatedly (Rueda *et al*, 1996 and Burton *et al*, 1989).

However, the choice of custom tray material often receives less attention.

LC acrylic resins have been in use since the 1980's (Jorge *et al*, 2003). Different manufacturing companies have done premarket testing with regards to its physical properties and actions. Independent researchers agree that its use has some advantages compared to its CC counterparts (Ling, 2004; Smith *et al*, 1999; Baker & Frazier, 1999; Brown & Kerr, 1998; Breeding *et al*, 1994 and Wirz *et al*, 1990). These advantages are: diminished hazardous effects; shortening of the preparation time; accuracy; strength; having acceptable rigidity and improved dimensional stability with polymerization shrinkage occurring within the light-curing box (Ling, 2004; Smith *et al*, 1999; Baker & Frazier, 1999 and Wirz *et al*, 1990).
However, its use is not without disadvantages, for example, the special curing unit needed is an additional equipment expense and the material is very hard once cured, making it difficult to trim (Smith *et al*, 1999 and Baker & Frazier, 1999). Reference is also made to the fine powder produced when the cured material is trimmed (Brown & Kerr, 1998).

The incorporation of the LC custom tray material into the dental training curriculum is a valuable aspect of change and modernization. Its use should rely on evidence-based scientific data.

By embarking on this research, it is hoped that more evidence will be produced to assist with these decision-making processes.

The research problem and hypotheses were developed with the help of available literature, clinical exposure and the laboratory work regarding the use of CC acrylic resin custom tray materials, its disadvantages and the alternatives available.

A brief review of the national and international literature is presented in the *second chapter*.

The *third chapter* highlights the research objectives and research hypotheses.

The research methodology, with complete description of sampling, method and statistical analyses for this research is outlined in the *fourth chapter*.

The *fifth chapter* illustrates the results (graphically and / or other) of the tests done.

The *sixth chapter* engages a brief discussion with regards to the methodology and at times the deviations from the literature. It also focuses on similarities between this study and the literature as well as the implications of the findings of this study.

Finally, the *seventh chapter* concludes the thesis with a summary of the main findings and a few recommendations extrapolated from this research.

CHAPTER 2

LITERATURE REVIEW

A brief review of the national and international literature, covering the period from 1980 to 2006, for the purpose of this study is presented in this second chapter.

2.1 Custom trays for complete removable dentures

As stated earlier, the role of custom trays in the construction of complete removable dentures is important to ensure a successful treatment outcome.

Ideally, the requirements of a custom tray and the material from which it is made should include the following features (Wirz *et al*, 1990; Burns *et al*, 2003 and Millstein *et al*, 1998):

a) Stability in air and in a moist environment,

b) volumetric stability over time,

c) moisture resistance,

d) rigidity (high modulus of elasticity),

e) adhesion of the impression material in the tray and

f) thickness of impression material layer control.

2.2 Custom tray materials

Different custom tray materials are available and are used by dental laboratories and at dental schools. But tray materials with the best chemical and physical properties, best user-friendliness and biocompatibility should be used (Smith *et al*, 1999;

Millstein *et al*, 1998; Rueda *et al*, 1996; Ogden *et al*, 1994; Breeding *et al*, 1994; Hitge *et al*, 1991 and Wirz *et al*, 1990).

2.2.1 Chemically-cured acrylic resin

The material for custom trays most often used is the polymethyl methacrylates (PMMA). The constituents of the CC acrylic resin include the following (Phillips, 1982):

Powder – polymethyl methacrylate polymer; a peroxide initiator and a pigment.

Liquid – methyl methacrylate monomer; a stabilizer and a cross-linking agent.

Several researchers have published their findings with regards to the properties of CC resin custom tray materials (Fehling *et al*, 1986 and Goldfogel *et al*, 1985). All studies concluded that the procedure for constructing CC acrylic resin trays was technique–sensitive and they recommended that manufacturer's instructions should always be followed, such as using the correct powder liquid ratio and covering the mixing bowl to prevent evaporation of the monomer.

The literature refers to the fact that impressions taken in these trays produce accurate dies and the material is fairly cheap. But the tray material is not rigid enough, thus limiting the type of impression material (elastic based type) used within these (Burton *et al*, 1989).

The dental literature focuses predominantly on the hazardous effects of the monomer and the dimensional stability of the CC acrylic resins (Scott *et al*, 2004; Martin *et al*, 2003; Leggat & Kedjarune, 2003; Millstein *et al*, 1998; Hochman & Zalkind, 1997; Rueda *et al*, 1996; Pettersen & Jacobsen, 1991; Gordon *et al*, 1990; Burton *et al*, 1989; Anderson *et al*, 1988; Fehling *et al*, 1986 and Goldfogel *et al*, 1985).

Toxicity, odor or even allergies can be experienced during and after fabrication (Scott *et al*, 2004; Martin *et al*, 2003; Leggat & Kedjarune, 2003; Hochman & Zalkind, 1997; Pettersen & Jacobsen, 1991 and Seppäläinen & Rajaniemi, 1984).

The effect of acrylic-related work on the non-dermatological systems such as circulatory, digestive and respiratory functions of patients is referred to in the literature (Scott *et al*, 2004 and Pettersen & Jacobsen, 1991). The dermatological reactions (seen on the fingers and hands), are due to contact with the residual monomer and the length of exposure to it, as in the case of dental technicians (Jorge *et al*, 2003; Hochman & Zalkind, 1997; Pettersen & Jacobsen, 1991 and Seppäläinen & Rajaniemi, 1984).
Martin *et al* (2003) also reported a case of Type IV delayed contact dermatitis seen in patients.

'Polymerization shrinkage' and 'stress relaxation' of the CC acrylic resin custom trays could lead to distortion of the final impression and thus ill fitting dentures (Rueda *et al*, 1996; Burton *et al*, 1989; Anderson *et al*, 1988 and Fehling *et al*, 1986). An interval (varying between researches) should be allowed between the fabrication and the use of these trays for taking of the final impressions (Rueda *et al*, 1996 and Fehling *et al*, 1986).

2.2.2 Light-cured acrylic resin

An alternative to the CC resin material is the LC acrylic resin and research on several of its properties has been conducted (Smith *et al*, 1999; Breeding *et al*, 1994 and Wirz *et al*, 1990).

The constituents of this material include the following:
urethane dimethacrylate matrix; acrylic resin copolymer and microfine silica filler (Baker & Frazier, 1999). The material is polymerized by exposure to light in a photocuring unit.
This newer LC acrylic material has many advantages compared to the CC material:
It has sufficient rigidity and can be used in thin areas; has excellent dimensional stability; has a shorter fabrication time (i.e. making and trimming); has uniform

thickness; is easy to use; gives a superior fit and has no aroma (Baker & Frazier, 1999 and Brown & Kerr, 1998). It is used in the undergraduate dental curriculum in several countries (especially in the US, UK & Germany) but it must still replace the CC acrylic resin in other dental schools as the most viable alternative (Petropolous & Rashedi, 2003; Smith *et al*, 1999 and Wirz *et al*, 1990).

2.3 Dimensional stability

Dimensional stability refers to maintaining the size and shape of a set material. Many researchers (Rueda *et al*, 1996; Breeding *et al*, 1994; Wirz *et al*, 1990; Burton *et al*, 1989; Anderson *et al*, 1988; Fehling *et al*, 1986 and Goldfogel *et al*, 1985) have commented on the dimensional stability of CC acrylic resin custom trays; the lack thereof and its effects on the final impression and eventually on the fit of the dentures.

The accuracy of impression materials have been studied and confirmed by researchers (Wirz *et al*, 1990). But, according to Fehling *et al* (1986), distortion of a final impression can be caused by the shrinkage of the CC acrylic resin custom tray. Although results in the different studies vary, there is consensus that, following the fabrication of CC acrylic resin custom trays, an interval before final impression taking should be allowed (different times according to different researches) (Fehling *et al*, 1986).

2.3.1 Measuring dimensional stability

Linear shrinkage of acrylic resin materials can be measured using several different types of instruments and test methods:

a) Linometer (de Gee *et al*, 1993),
b) Dilatometer (Cook *et al*, 1999 and Lai & Johnson, 1993),
c) Gas pycnometer (Cook *et al*, 1999),
d) Bonded-disk technique (Alvarez-Gayosso *et al*, 2004),
e) He-Ne scanning laser beam (Fano *et al,* 1997),
f) Buoyancy tests (Rosin *et al*, 2002 and Cook *et al*, 1999) and
g) Digital calipers.

de Gee *et al* in 1993 (cited by Rosin *et al*, 2002 and Park *et al*, 1999) assembled the **linometer** and recommended its use as it is simple, fast and easily used without being affected by temperature fluctuations. According to de Gee *et al* (1993), it offers an easy way to determine polymerization shrinkage. The one major disadvantage with using this instrument is that the measuring time must not exceed 90 seconds as recorded by the attached computer (Park *et al*, 1999).

The use of **dilatometers** (water- and mercury-based) is 'labor intensive.' The machines are sensitive to temperature fluctuations, thus maintaining a constant temperature is critical to the success of using these instruments (Cook *et al*, 1999 and Lai & Johnson, 1993). The mercury-based type is also regarded as a health hazard and the water-based one may also be influenced by the absorption of water by the resin (Cook *et al*, 1999).

The **gas pycnometer method** was found to be efficient, less 'labor intensive' and accurate and is recommended when the total shrinkage measurement of a material is critical (Cook *et al*, 1999).

In the **bonded-disk method** the average contraction rate is measured and the extent of shrinkage is deduced from this (Alvarez-Gayosso *et al*, 2004). Calculations leave a method open for error.

With the **He-Ne scanning laser beam method**, shrinkage is not induced by the laser and as small samples can be analyzed with a low margin of error, this method is deemed reliable (Fano *et al*, 1997).

The **buoyancy test method** measures the density of wet and dry specimens and the shrinkage is then calculated (Rosin *et al*, 2002). This method is found to be insensitive to temperature changes but sensitive to air bubbles attached to the resin surface (Cook *et al*, 1999).

The **digital caliper** is fairly simple to use, accurate (giving a measurement of up to 2 decimals) and reliable. It is also unaffected by temperature changes, inexpensive and easily obtainable. Due to the advantages, it was decided to use this instrument in this study.

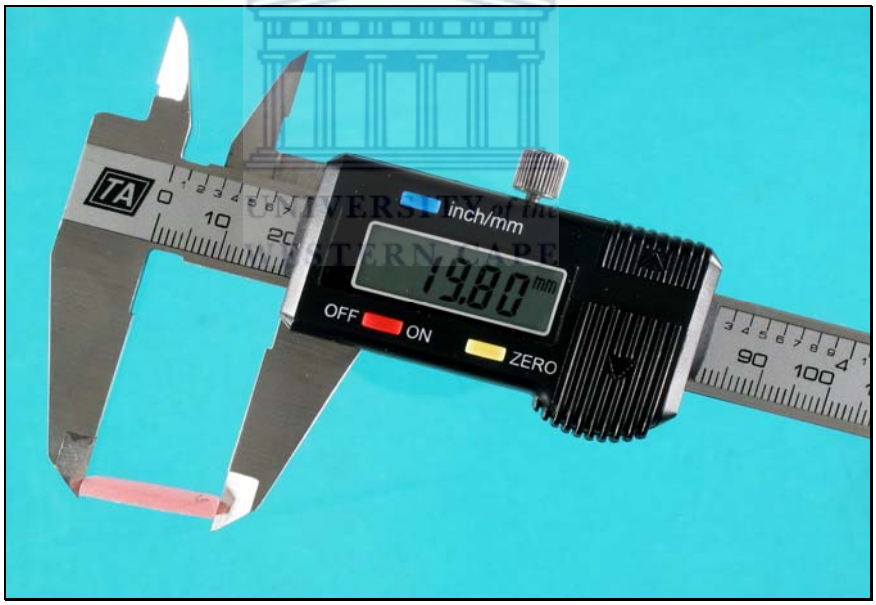


Figure 1: A digital caliper

2.3.2 Specimen storage

Some researchers suggested the soaking of acrylic specimens in water for approximately 30 days hoping to allow expansion in order to compensate for the polymerization shrinkage (Anderson *et al*, 1988). According to several studies the storing of samples in water displayed this dimensional expansion (with an increase in linear measurements only), but some said this failed to compensate for the initial polymerization shrinkage (Segerström *et al*, 2005 and Anderson *et al*, 1988). In the study by Segerström *et al* (2005), the height, width and length were measured with a micrometer and only an increase in width and height, not in linear measurement was displayed. Thus, expansion in all dimensions of the specimen did not occur.

2.4 Fracture Toughness

Toughness is the ability to absorb energy without fracture. It is measured by the total area under a stress–strain curve and it is expressed in J/m^3 units (Phillips, 1982). The **fracture toughness**, expressed as ***stress intensity factor*** **[K_{IC}]**, is the intrinsic characteristic of a material concerning its resistance to crack (Phillips, 1982). K_{IC} *is measured in* $MPa.m^{0.5}$ (Phillips, 1982). "It is a measure of the energy needed or stress intensity to initiate and propagate a crack in a material in an unstable manner" (Bonilla *et al*, 2003 and Fujishima & Ferracane, 1996). Fracture toughness is thus a good measure of a material's strength and allows finer discrimination of a material's properties. It is also a better reliability indicator for its clinical behavior and for comparing materials than just measuring the tensile and flexural strength (Gegauff & Wilkerson, 1995).

An increase in the value of the K_{IC} thus indicates that the material fractures less easily and that it has enhanced or increased fracture toughness (Segerström *et al*, 2005).

Fracture toughness is dependant on:

- specimen geometry (height, length, width & thickness);
- crack-tip sharpness;
- filler particle size;
- composition of matrix (concentration and distribution of filler particles) and matrix-interface adhesion (Fujishima & Ferracane, 1996).

2.4.1 Specimen preparation

Specimens can be fabricated using metal, plastic or perspex templates. But as we are dealing with specimens that must be placed in a light-curing machine, it is advisable to fabricate and place these in a template that transmits light. Thus, in this study, perspex was used (Figure 2).

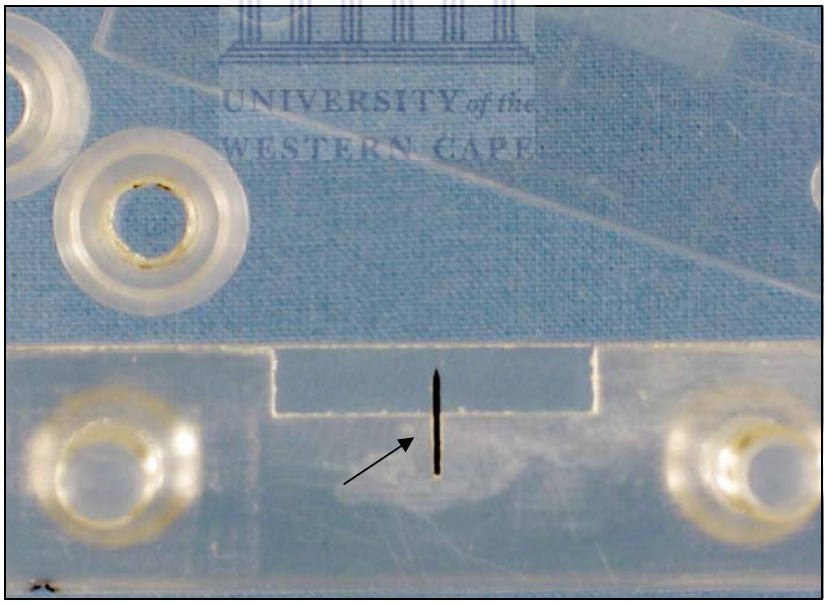


Figure 2: Perspex template with blade for the notch (arrow)

The use of a template eliminates the need for machining the specimen to its desired dimension. Machining could increase the chance of error: it could produce multiple cracks and irregularities on the surface of the specimen that could initiate the crack process and affect the final results (Neihart *et al*, 1988).

According to some researches, K_{IC} is affected by specimen storage conditions - wet or dry (Bonilla *et al*, 2003); by the testing environment (wet or dry) and/ or by the need for a precrack versus a mold notch (Gegauff & Wilkerson, 1995).

Other researches have found that wet or dry storage testing has not significantly affected the results of K_{IC} (Sung-Hun & Watts, 2004 and Bonilla *et al*, 2003). In some instances, a higher K_{IC} value for wet storage was found and in other instances no difference in K_{IC} values for either wet or dry storage was found (Bonilla *et al*, 2003).

They also suggested that the higher K_{IC} values could be due to the constituents of the resin matrix and not necessarily due to the storage media (Bonilla *et al*, 2003). This is in agreement with Lloyd's (1984) work where he found that K_{IC} for PMMA was higher when tested in a wet setting (cited by Bonilla *et al*, 2003 and Gegauff & Wilkerson, 1995). Similarly, according to Segerström *et al* (2005), a resin with PMMA in its matrix has greater water absorption abilities than other materials and a higher K_{IC} value, but this still does not affect the stress intensity significantly.
Gegauff & Wilkerson (1995) in their article concluded that wet storage changed the K_{IC} measurement, yet Ferracane *et al* (1987) says in his research that the K_{IC} has decreased.

From the literature, no clear guidelines or conclusive rules with regards to specimen storage could be found. Thus the specimens in this study were stored in a dry environment at room temperature.

2.4.2 Testing fracture toughness (K_{IC})

Many tests are described by researches that measure K_{IC}, for example:

1) Single-edge notched method (Ferracane *et al*, 1987);
2) Compact tension method (Fujishima & Ferracane, 1996);
3) Short rod with chevron notch method (Fujishima & Ferracane, 1996);
4) Double torsion method (Fujishima & Ferracane, 1996);
5) Indentation hardness technique - described by Parmqvist in 1962 (cited in Rosenstiel and Porter, 1989a and 1989b) and the
6) Ring specimen method (Fujishima & Ferracane, 1996).

Impact tests as the Izod and Charpy configuration tests are included amongst these tests, with its various specimen modifications and notches. Although the impact tests are popular, these do not measure the intrinsic material properties since it depends on too many factors i.e. specimen dimensions; notch depth and radius and impact velocity (Zappini *et al*, 2003).

Different values of K_{IC} have been reported for the same material, but according to Fujishima & Ferracane (1996), because K_{IC} is a characteristic property of a material, therefore its value should be independent of the method used for measurement.

The three-point-bending test (testing ultimate tensile strength, which is the stress at fracture) as described in the ISO standard 1567 is a commonly used test method (Zappini *et al*, 2003 and Phillips, 1982). Although three-point bend testing is not the gold standard for assessing clinical durability, it is appropriate in that it is a predictor of clinical durability by measuring the ultimate tensile strength and provides reliable results when comparing materials (Bonilla *et al*, 2003 and Gegauff & Wilkerson, 1995).

Single-edge notch testing has the advantages of ease of specimen fabrication, reproducibility, accuracy and testing, and the disadvantage of having uncontrollable 'accelerated crack formation' (Stafford *et al*, 1980). Compared to single-edge notched specimens, the tapered cleavage ones are difficult to fabricate but provide more information with regards to the fracture process (Stafford *et al*, 1980).

The mechanical properties must also be determined by testing the tensile strength (TS) derived from flexure testing (which is the force at fracture of a specimen subjected to a load), as this would be a more reliable indicator of the materials clinical performance (Gegauff & Wilkerson, 1995). TS and K_{IC} is not related and the material with high TS does not necessarily have high K_{IC} (Gegauff & Wilkerson, 1995).

2.5 Cross - linking

The physical and mechanical properties of a cured material are determined by its composition. These properties also influence its clinical performance (Arima *et al*, 1996a). Researches have alluded to this, with special reference to the matrix composition and its effect on K_{IC} (Bonilla *et al*, 2003). The type of filler particles, distribution and concentration of particles within the matrix will influence the stress intensity (Bonilla *et al*, 2003).

Cross – linking is the chemical bonds between different chains that make up the polymer molecule. The presence of cross-linking agents in the powder or liquid of resins has been shown to affect the properties of a material, for example, increasing its craze resistance, stiffness and surface hardness (Segerström *et al*, 2005; Arima *et al*, 1996b and Price, 1986). The presence of cross-linkages up to 15% will ensure the hardness (the resistance of a material to plastic deformation measured under an indentation load) and brittleness (the inability of a material to deform plastically) of the polymer but when added at a higher percentage will have a negative effect on its

properties (Segerström *et al*, 2005; Arima *et al*, 1996b; Price, 1986 and Phillips, 1982). The degree of cross-linking has an effect on the K_{IC} and brittleness (Stafford *et al*, 1980).

Cross-linking agents with an adequate chain length also show greater fracture toughness (Segerström *et al*, 2005 and Price, 1986). Different types of cross-linking agents either within the polymer or monomer will also have a different effect on the mechanical properties of that material (Segerström *et al*, 2005). The curing method (light or chemical) also has an influence on the hardness of the set materials (Phillips, 1982).

The Dynamic Mechanical Analysis (DMA) is the composition analysis of the individual components (monomer/ polymer) of the material. PMMA polymers can easily be separated into its individual components (monomers) by heat and these can then be analyzed (Jones *et al*, 1991). Analysis is achieved using ***infrared spectroscopy*** together with procedures called *high performance liquid chromatography* and *gel permeation chromatography* (Segerström *et al*, 2005; Arima *et al*, 1996a; Jagger & Okdeh, 1995 and Jones *et al*, 1991).

Infrared spectroscopy provides a large set of content information when viewing the spectrum (Gunzler & Gremlich, 2002). It can also state the structural group of a material which is not easily achievable by other methods and as it is characteristic of a material it can be used to identify it (Gunzler & Gremlich, 2002).

Infrared spectroscopy tests the degree of conversion of the double bonds during the polymerization process (Ferracane *et al*, 1987). An increase in conversion means that the K_{IC} will be adversely affected and the brittleness of the polymer matrix will be increased (Ferracane *et al*, 1987).

The molecular weight of powders of the acrylic resin is determined using the high performance liquid chromatography and gel permeation chromatography column test methods (Arima *et al*, 1996a; Jagger & Okdeh, 1995 and Jones *et al*, 1991). The

spectra achieved during these procedures can be utilized to interpret the mechanical properties of the materials, such as the presence of cross-linking agent, the molecular weight and the extent of co-polymerization (Whiting & Jacobsen, 1980).
With regards to light-activated materials, composition analysis can also be achieved of its uncured and cured forms using the same testing methods as mentioned previously but specimens have to be prepared using specific methods.

The sodium chloride discs used in infrared spectroscopy testing are clear and round, are hygroscopic and once placed in an infra-red spectrometer on its own, nothing will be recorded. Only once the test material is placed on the disc, will it be recorded in the spectrometer and shown on the attached computer screen.

2.6 Questionnaire

A questionnaire is an important instrument of research and a tool for data collection (Oppenheim, 1992). Its main function is measurement, which is specified on the questionnaire and in this study that was:
'User-friendliness of LC and CC acrylic resin custom trays.'
The process of drawing up a questionnaire involves careful designing, focusing on the required outcomes and piloting to eliminate ambiguities.

The following issues need to be considered during formulation of the questions (Oppenheim, 1992):

1) Type of data collection tools – i.e. questionnaires;
2) Method of approach to sample – i.e. stated purpose of research, length of questionnaire, confidentiality and anonymity;
3) Build-up of question sequences – i.e. order of questions and scales; and
4) Type of questions – i.e. closed questions with pre-coded answer categories.

Piloting of a questionnaire is carried out to eliminate ambiguities and to ensure that it yields usable data. Once piloted, the questionnaire can be changed and reformulated. The reliability (the ability to produce consistent results), validity (ability to measure what is supposed to be measured) and the practicality (the convenience and interpretability) must be ensured to make a questionnaire a sound and acceptable measuring tool (Oppenheim, 1992).

A Likert scale is used to measure attitudes, preferences and subjective reactions. On a psychometric scale of this nature, respondents specify their level of agreement or disagreement to each list of statements or questions, most often on a five-point scale (Oppenheim, 1992).

2.7 Summary

All the studies involving tests of the custom tray materials reviewed, were conducted in foreign countries, of which many have changed their undergraduate didactic teachings. Anecdotal evidence suggests that the same type of problems (varying with the different personnel exposed to this material) is also experienced in this country, yet no researched evidence is available. This study aims to test the LC and CC acrylic resin materials and to provide evidence regarding some of the properties of the LC acrylic resin material. Recommendations for future research will also be made with regards to these materials in order to establish a larger base of information.

CHAPTER 3

RESEARCH OBJECTIVES

3.1 Aim

The aim of this study was to collect information on the handling and mechanical properties of LC acrylic resin and compare it to the CC acrylic resin custom tray material. The study could assist in making an informed decision on the selection of a material for didactic and clinical training purposes.

3.2 Objectives

1. To determine the dimensional stability of the LC acrylic resin custom tray material.
2. To compare the fracture toughness of the LC acrylic resin with the CC acrylic resin (as control) using the three-point bend test.
3. To establish "user-friendliness" of the LC custom tray material amongst dental students by means of a questionnaire.

3.3 Null hypotheses

1. The LC acrylic resin material is not more dimensionally stable than the CC acrylic resin material.

2. The LC acrylic resin material is not stronger than the CC acrylic resin material.

3. The LC acrylic resin material is not more user-friendly than the CC acrylic resin material.

CHAPTER 4

METHOD AND MATERIALS

The methodology for all three sections of this study will be covered in this chapter. Each section will be dealt with separately but reference will be made to the similarities and /or differences between the specific procedures.

4.1 Dimensional stability

Twenty LC acrylic resin (Megatray, Megadent, Radeberg, Germany) specimens with configurations of 2 x 4.2 x 20mm, as set out in the guidelines of the American Society for Testing Materials were fabricated using a custom-made perspex template (Bonilla *et al*, 2003 and ASTM, 1990) (Figure 3). The template was lined with a very thin layer of vaseline and filled with the resin. The cover was placed over the specimen and compressed to fill the entire mold, removing all the excess with a wax knife. The specimens were cured in a light-polymerizing unit (Megalight Mini, Megadent, Radeberg, Germany) for 3min. The template was taken apart for easy removal of the specimens with a wax knife. The specimens were placed in the curing unit where it was re-cured for another 3minutes to ensure complete polymerization. The specimens were examined for any voids and defects under a light microscope (Wild, Heerbrugg, Switzerland) at a magnification of 10 x and those with visible defects were discarded.

Thirty minutes after fabrication, the length of each LC specimen was measured (in mm) three times with a digital caliper (Power Seller, Canada) and these measurements were noted. The average of the three values was then calculated for each specimen. This same measuring protocol was ensued 1hour, 24, 36 and 48 hours later. The values were all recorded and again the averages were calculated.

The average shrinkage value for all specimens per time interval was calculated by subtracting the average dimensions from 20mm, the length of the template, which served as the standard to compare possible dimensional changes (Figure 3). The median of these average shrinkage values was used to analyze the shrinkage over time.

A pilot study was first conducted to verify the methodology of this test.

The median, minimum, maximum, first and third quartiles of the averages were calculated to obtain descriptive statistics of the raw data via MS Excel. The results for dimensional change were compared using the Wilcoxon Rank Sum test. A p-value of less than 0.05 was regarded as significant.

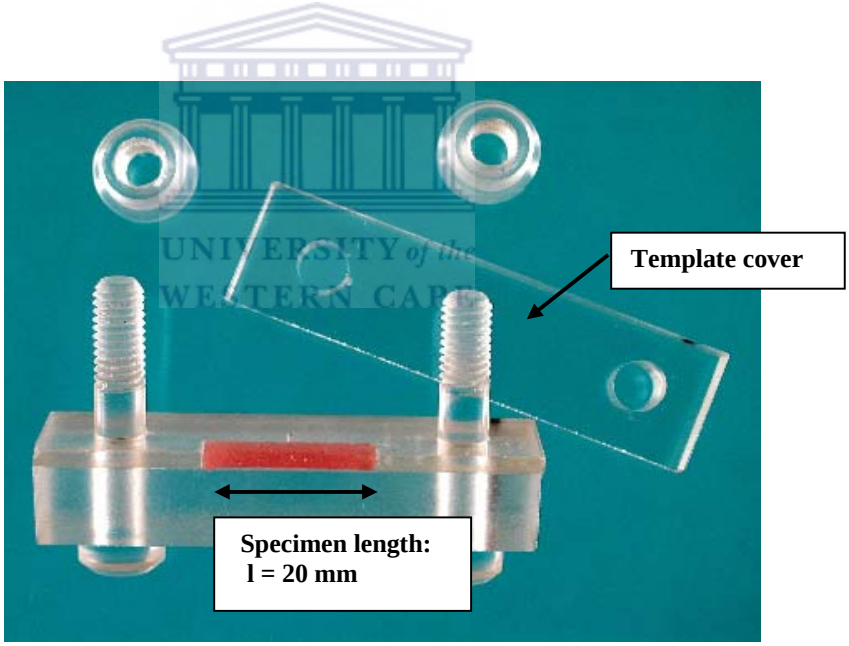


Figure 3: Perspex template with acrylic specimen (specimen length = 20mm)

4.2 Fracture toughness

The single-edge notched beam test as described by Bonilla *et al* (2003) was used to determine the K_{IC} of the LC acrylic resin (Megadent, Radeberg, Germany) and the CC (Excel special tray material, Wright Health Group, United Kingdom) acrylic resin tray materials. The test specimen configuration conformed to the guidelines as laid down by the American Society for Testing Materials for this test, Standard E-399 (Bonilla *et al*, 2003 and ASTM, 1990). A custom-made perspex template was used to form 20 specimens (n=20) of the LC material with the same specifications and method as described in 4.1. A steel blade with a cutting edge on both sides was attached to the one side of the template. This blade creates a 3mm centrally placed notch on the one edge of the specimen, now known as a single-edge notched specimen (Figure 4). These were then cured twice in the light-polymerization unit as described in 4.1.

The same template was used to form the CC specimens, and the specifications were the same as the LC specimens. The polymer and monomer in the ratio 2:1 by measurement was mixed for 12 seconds in a clear glass jar with a stainless steel spatula as recommended by the manufacturers.

Specimens were again viewed under a light microscope at a magnification of 10 x (Wild, Heerbrugg, Switzerland) and those with notable defects were again discarded. Specimens were stored in a dry environment at room temperature for 24hours before testing.
A pilot study was conducted to verify the methodology of this intended test.

A universal testing machine (Model 1446, Zwick, Germany) was used to apply a central load perpendicular to each specimen. The specimen was suspended centrally over two adjustable supports which were placed 17mm apart as described in Standard E-399 (Bonilla *et al*, 2003 and ASTM, 1990).

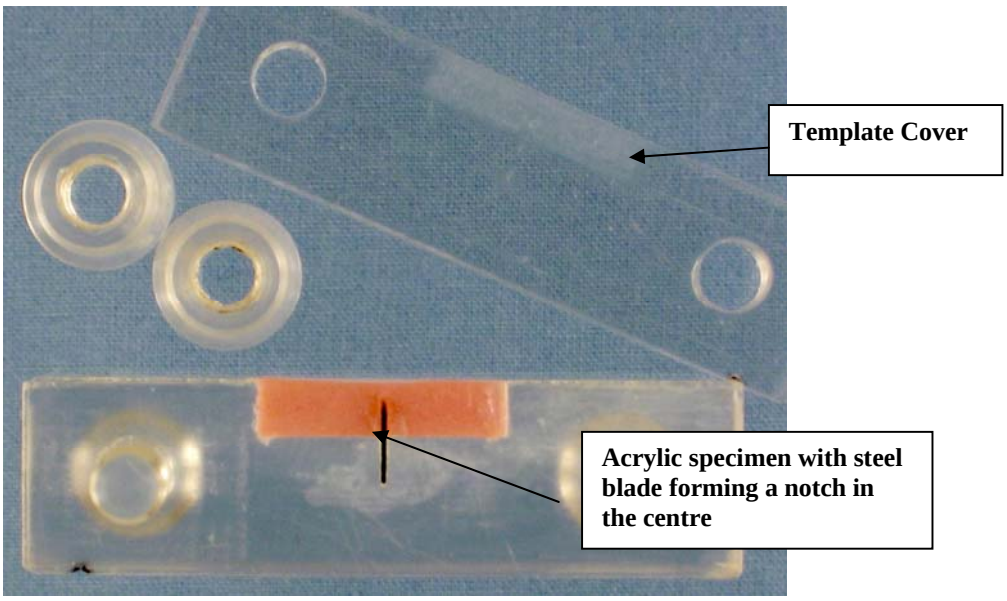


Figure 4: Perspex template with notched acrylic specimen

The load was applied in line with the notch in a three-point bending mode at a crosshead speed of 0,5mm/min until the specimen fractured. This material testing machine was attached to a computer (Windows XP with Testxpert software program) to record the load values (Force in N), when the LC and CC specimens fractured.
The force measured at fracture for both LC and CC acrylic specimens was read from the computer and recorded. These values were entered into the equation below and the fracture toughness was calculated for each specimen.

A visual light microscopic at a magnification of 10 x (Wild, Heerbrugg, Switzerland) inspection of the cracked parts was performed to ensure that the fractured plane was through the center of the specimen.

4.2.1. Statistical analysis

Stem-and-Leave diagrams introduced by John Tukey give a clear indication of the spread /dispersion of forces used to cause specimen fracture.

Probability Density Frequency (PDF) line graphs give more precise information and interpretation of recorded force values compared to the histograms, which provide crude density estimates of where these values are situated.

Fracture toughness (K_{IC} in $MPa.m^{0.5}$) was calculated via MS Excel using the formula (Bonilla *et al*, 2003 and ASTM, 1990):

$$\mathbf{K_{IC} = (PL/\ bw^{1.5})\ f\ (a/w)}$$

Where,

$$f\ (a/w) = 3/\alpha\ (a/w)^{0.5}\ \{1.99-(a/w)(1-a/w)\ x\ [\ 2.15-3.93a/w + 2.7(a/w)^2]\}$$

and,

α = $2(1+2a/w)\ (1-a/w)^{1.5}$

K_{IC} = Stress Intensity Factor

w = width of specimen

b = thickness of specimen

a = crack length

P = load at fracture

L = span; distance between two supports.

The dimensions from the given specifications that were included in the equation are:

L = 17mm;

a = 3mm;

b = 2mm and

w = 4.2mm (Bonilla *et al*, 2003 and ASTM, 1990).

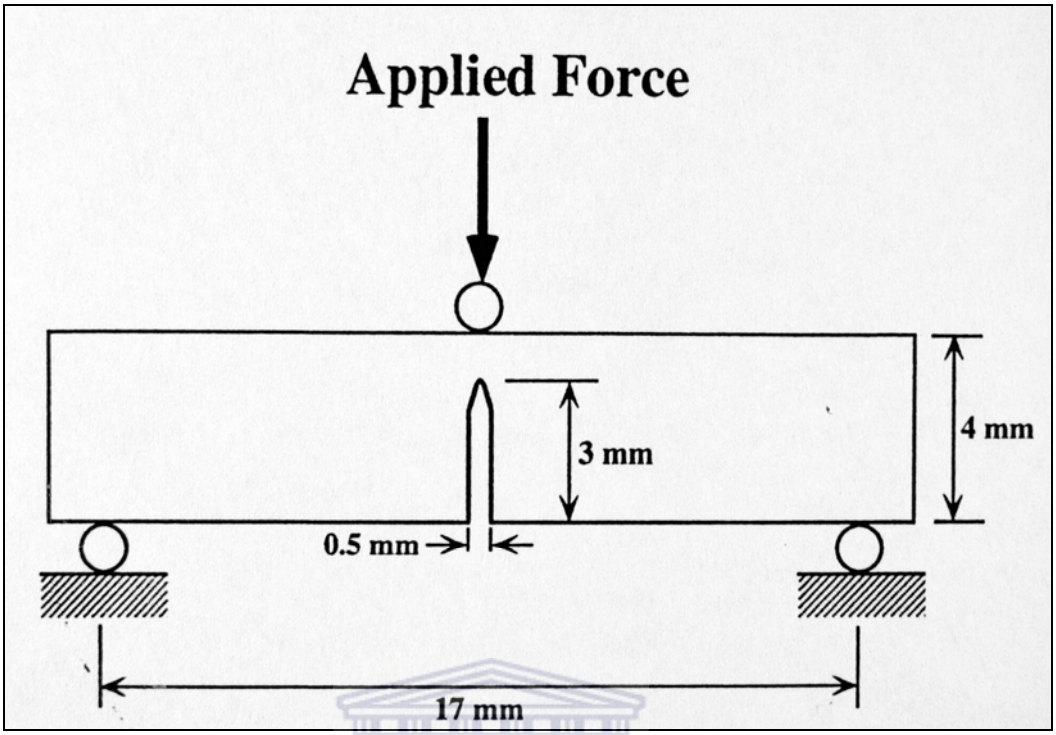


Figure 5: Diagrammatic representation of specimen and its dimensions (Bonilla *et al*, 2003).

The mean, median and standard deviation of the results were computed.

The Wilcoxon Sum Rank test was utilized to analyze and compare the fracture toughness (K_{IC}) values between LC and CC specimens. A p-value less than 0.05 was considered significant.

The distribution of forces was observed with the Stem-and-Leave statistical method. The distribution of forces was also interpreted using Histograms and Probability Density Estimates or Frequency (PDF) in the form of a line graph.

4.3 Infra-red spectroscopy

Analysis of the individual components of the LC and the CC material as well as the polymerized products was performed using the method of **infra-red (IR) spectroscopy.** The IR spectrum of the powders and liquids were determined from the FT- IR spectrometer, model 270-30 (Paragon 1000 FT-IR, Perkin-Elmer with Perkin-Elmer Spectrum software). In IR, light is reflected off the surface of the sample and there is no back reflection because the rays are absorbed. This method was developed for quick screening and the wavelengths can be viewed and read from the attached Pentium 4 computer.

Polymer: Polymer was dissolved in potassium bromide powder (1:10 parts) in a petri-dish to form a paste and these were then placed in the spectrometer. The wavelengths were read from the graph shown on the attached computer.

Monomer: One or two drops of monomer were placed between two sodium chloride discs; the resultant thin film of liquid between the discs was then placed in the spectrometer. This is also known as the Thin-Film technique for testing. The wavelengths were read from the computed graph.

Powder of cured CC resin: A powder was created from the cured material and dissolved in potassium bromide as above to form a paste. This was placed in the spectrometer and the graph viewed from the computer.

Unpolymerised specimen of LC resin: A small wafer of unpolymerized light-curing material was placed in the petri-dish and was dissolved in dichloromethane (CH_2Cl_2) and briefly held over a heat source to aid dissolution. A pink liquid was obtained and a few drops were placed on the same disc after it was cleaned first. The second disc was placed over this and these were clamped together, and then viewed in the spectrometer. The graphs were read from the attached computer.

Powder of cured LC resin: A powder was created from the cured material and dissolved in potassium bromide as above. It was placed in the spectrometer and the wavelengths were read from the computer.

4.4 Survey

A **questionnaire** was drawn up to compare the use and handling properties of the CC and LC acrylic resin used in the undergraduate training program of the University of the Western Cape. The instructions and inclusion and exclusion criteria were stipulated on the front page (Appendix 3). The inclusion criteria were the following: undergraduate students; laboratory and clinical experience with both types of materials (a requirement of the undergraduate program); the custom trays used for complete denture construction only.

The format of the questionnaire entailed a set of closed questions and statements with several options following the guidelines according to the Likert scale (Oppenheim, 1992). The options included a range of positive and negative responses for each question, and emphatic negative and positive responses were also accommodated for. No neutral or "don't know" options were given (Appendix 3.1).

Two drafts were piloted amongst students and staff before the questionnaire was finalized and ready for distribution. The questionnaire was translated into Afrikaans to ensure understanding of questions amongst students whose first language was Afrikaans (Appendix 3.2).

The sample for this survey included the 4th and 5th year undergraduate dental students of the University of the Western Cape. The researcher personally distributed the questionnaire to the students to complete and emphasized the inclusion /exclusion criteria and instructions to the students. It was also re-iterated that participation was voluntarily and that anonymity would be ensured. The purpose of the study was explained: to analyze the acceptance of the LC acrylic (the newer material) over the

CC acrylic resin (the norm in training) and to assess the recommendations of the 4th and 5th year students. The questionnaires were collected immediately on completion by the researcher.

The data was identified and entered into MS Excel, then analyzed by means of frequency tables and Chi-square tests. Cross-tabulation configurations were conducted to analyze and interpret the responses of the students and the significance of differences in preference amongst the different classes was determined by McNemer tests. A p-value of less than 0.01 was considered to be significant.

CHAPTER 5

RESULTS

The presentation of the results will be done in four sections as this study incorporated 4 different tests:

1. Dimensional stability
2. Fracture toughness
3. Infra-red spectroscopy and a
4. Survey.

The specimen testing environments were the same. The specimens for dimensional stability and K_{IC} were different, the ones for K_{IC} had a central notch on one side and both LC and CC specimens were prepared for this test.

5.1 Dimensional stability

The length for the LC acrylic resin specimens at the different time intervals was recorded and the average of the 3 values was calculated (Appendix 4). The average shrinkage value for these specimens per time interval was calculated by subtracting the average dimensions from 20mm (length of the template). The median of these averages was used to determine shrinkage over time (Table 1).

The medians of the average linear shrinkage values in mm for the LC acrylic specimens at the different time intervals were as follows:

At 30min - **0,230**; at 60min - **0,245**; at 1440min - **0,200**; at 2160 min - **0,265** and at 2880min - **0,280** (Table 1).

minutes / shrinkage	0	30	60	1440	2160	2880
Max	0	0.440	0.490	0.400	0.430	0.470
Third quart	0	0.260	0.280	0.212	0.290	0.320
Median	0	0.230	0.245	0.200	0.265	0.280
First quart	0	0.198	0.180	0.190	0.227	0.270
Min	0	0.160	0.140	0.170	0.210	0.240

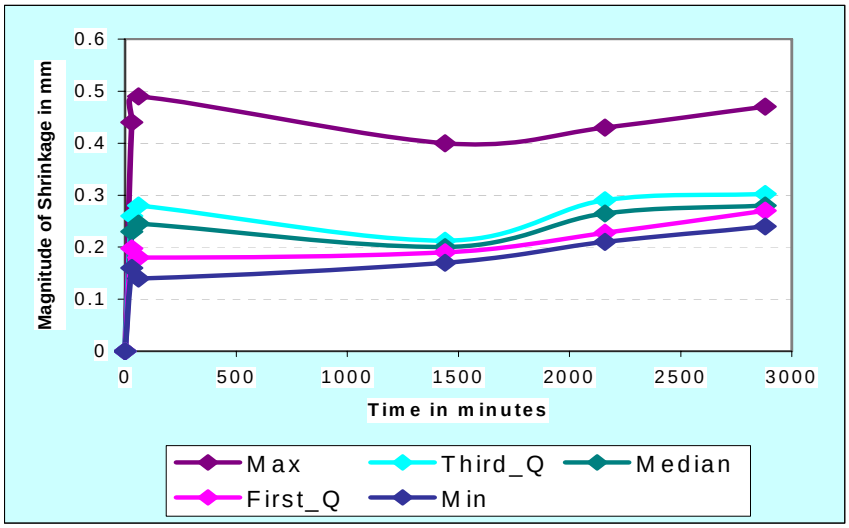
Table 1: Shrinkage in mm of LC acrylic resin specimens at different time intervals (Max = maximum; Min = minimum; quart = quartile)

Compared to the standard (of 20mm), the average shrinkage at all the different time intervals were highly significant according to the Wilcoxon Signed Rank test ($p<0.05$).

With reference to the medians of the average shrinkage values, an increase in shrinkage over time was noted.

The difference in the medians of the shrinkage values between the different time intervals were however not significantly different according to the Wilcoxon Signed Rank test ($p>0.05$). The differences in the medians between the intervals 30 to 60 minutes and 36 to 48 hours were only 0.015mm at both instances.

The median, interquartile ranges and minimum and maximum values for shrinkage of this LC acrylic resin special tray material are shown on Graph 1 (below).



Graph 1: Average shrinkage of LC acrylic resin specimens

The average linear shrinkage changes are stipulated on the graph, with the minimum values showing a clear and steady, but insignificant increase in shrinkage over time (Graph 1).

Even within the first 30 minutes, the average shrinkage was insignificant.

Sequential shrinkage is the amount of shrinkage in mm between consecutive time intervals. The average shrinkage sequentially compared to the standard of 20mm was highly insignificant, as seen on the graph above.

The variability of the distribution at 1440 minutes was less than at 30 minutes, but it still has a long tail of shrinkage. The distribution at 1440 minutes was highly leptokurtic.

5.2 Fracture toughness

5.2.1 Force

The force expressed in Newtons (N) measured at fracture for both LC and CC acrylic resin specimens was read from the computer attached to the material testing machine (Appendices 5 & 6).

The values of the force recorded are shown in Table 2. The force measured at fracture was much larger for the LC acrylic specimens and was in the range of 3.45-17.01N (Table 2). In comparison, the force at fracture of the CC acrylic specimens is in the range of 0 - 2.79N (Table 2). There was no overlap in force values recorded for the two different types of materials tested (Table 2).

LC	CC
Specimens	Specimens
3.45	0
4.07	0
6.11	0
7.61	0
8.64	0.37
8.65	0.5
8.83	0.7
9.33	1.03
9.61	1.09
10.28	1.1
11.4	1.15
11.91	1.21
12.01	1.46
12.78	1.52
12.79	1.6
13.54	1.77
13.6	1.96
14.13	1.97
15.29	2.06
17.01	2.79

Table 2: Values of computed force at breakage

According to the Wilcoxon Sum Rank test, a significant difference between force values at breakage of the two materials was noted ($p<0.05$).

The Stem-and-Leave diagram below showed that the dispersion of forces is over a larger area with the LC acrylic specimens (Figure 6). The force values, not overlapping, were very evident with this analysis too (Figure 6). The force values needed to fracture the CC acrylic specimens were below 2.8 N compared to the lowest force needed to fracture the LC specimens at 3.5N. The highest value of the force needed to fracture the LC acrylic resin specimen is 17,01N. That is, the lowest value for the LC specimen was still higher than the highest value for the CC specimen.

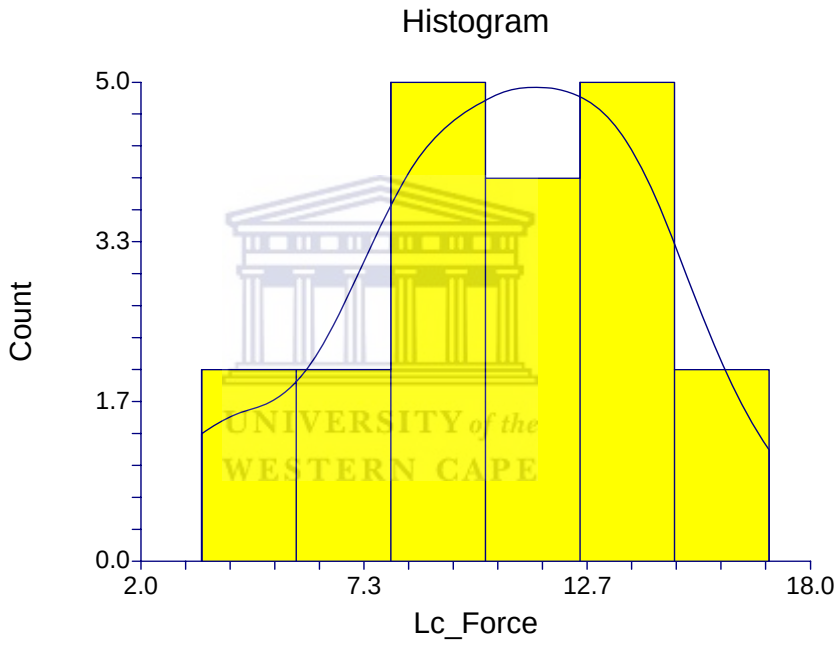
Chemically - cured		Light - cured	
Stem	***Leaves***	***Stem***	***Leaves***
0	00004 57	0	
1	01122 5568	1	
2	0018	2	
3		3	5
4		4	1
5		5	
6		6	1
7		7	6
8		8	678
9		9	36
10		10	3
11		11	49
12		12	088
13		13	56
14		14	1
15		15	3
16		16	
17		17	0

Figure 6: Stem-and-Leave diagrams of force values

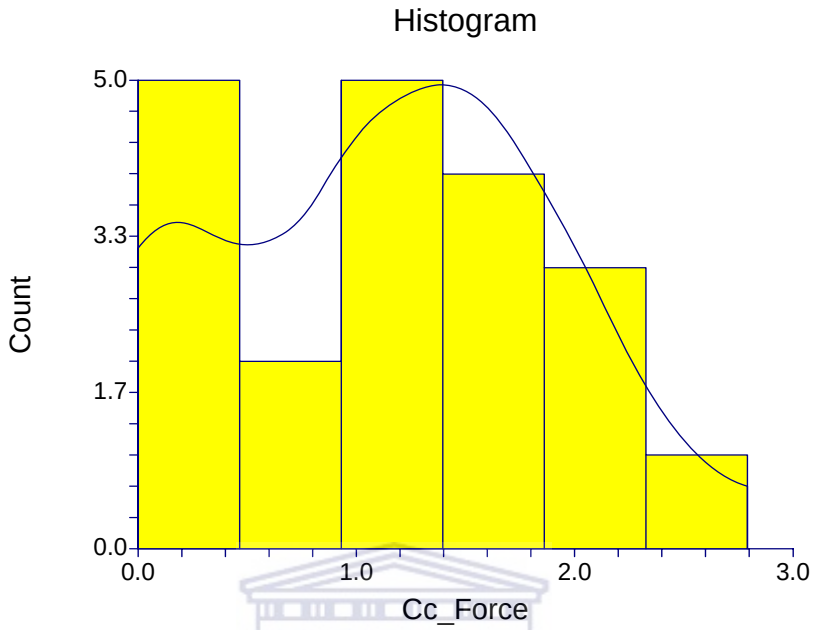
of CC & LC acrylic resin specimens.

Graphs 2 and 3 represent probability density estimates. The lines are continuously smooth and give more precise interpretation of information and the blocks represent histograms that are more crude density estimates.

Graph 2 shows that the majority of force values and the range of force values are acceptable and this is indicated on the graph by the plateau it forms.



Graph 2: Probability density estimates of LC force in Newton at breakage



Graph 3: Probability density estimates of CC force in Newton at breakage

Graph 3 shows that almost no force is needed to fracture the CC specimens and this account for the clustering near 0. This is an indication that this material is weaker. The curvature of graph 3 is decreasing towards the larger values, which implies that the majority of force values are in the region of the smaller values.

The Histograms and the Probability Density Estimates (line graphs) of the force needed to fracture LC and CC resin specimens show that the LC specimens are much stronger and need more force to break and that the CC specimens are significantly weaker ($p<0.05$) (Graphs 2 and 3).

5.2.2 Fracture toughness

The fracture toughness (K_{IC}) expressed in MPa.m$^{0.5}$ was calculated from the formula:

$$\mathbf{K_{IC} = (PL/\ bw^{1.5})\ f\ (a/w).}$$

Once the force at breakage was determined and values read from the computer, these values were entered into the equation and used to complete the calculations. The fracture toughness for the LC and CC specimens was calculated via MS Excel (and manually) to ensure a zero margin of error (Appendices 5 & 6).

The K_{IC} for the LC specimens ranged from 21.461-105.815 MPa.m$^{0.5}$ and for the CC specimens from 0-17.355 MPa.m$^{0.5}$ (Figure 7).

It can be concluded from these calculations that the K_{IC} for the LC specimens is greater compared to that of the CC specimens (Appendices 5 & 6).

Chemically - cured		Light - cured	
Stem	***Leaves***	***Stem***	***Leaves***
0	00002 34677 7899	0	
1	01223 7	1	
2		2	15
3		3	8
4		4	7
5		5	4458
6		6	04
7		7	145
8		8	00458
9		9	5
10		10	6

Figure 7: Stem-and-Leave diagrams of K_{IC} values of CC- & LC- acrylic resin specimens.

The Stem-and-Leave diagram (above) shows that the values for K_{IC} are distributed over a larger area for the LC specimens compared to the CC specimens (Figure 7).
When this analysis was done it also showed that the K_{IC} values also did not overlap and this is very clearly indicated by this diagram (Figure 7).
The highest K_{IC} value for the CC specimen is 17,355 and the lowest value for the LC specimen is 21.461 as seen on figure 7 ($p<0.001$).

	LC	CC
Min	21.46	0.00
1st Q	53.79	2.91
Median	67.43	7.00
3rd Q	80.73	10.22
Max	105.82	17.36
Mean	65.64	6.93
SD	22.26	4.98
Interquartile	26.94	7.31

Table 3: Fracture toughness in MPa.m$^{0.5}$ of LC & CC specimens.

The mean, median and standard deviation (SD) of the stress intensity are indicated in Table 3 above.
The maximum (max), minimum (min), first and third quartile (Q) ranges of the fracture toughness can be viewed in Table 3 as well.

The median for the LC specimens is 67.43 and for the CC specimens 7.00.
The mean for the LC material is 65.64 and for the CC material is 6.93. The variability between the two materials, in this study, indicates that the LC material is 10 times stronger than the CC material.
This can also be clearly indicated by calculating the coefficient of variation between the two materials as: SD / Mean x 100%. For LC it is 33.91% and CC, 71.86%.

5.3 Infra-red spectroscopy

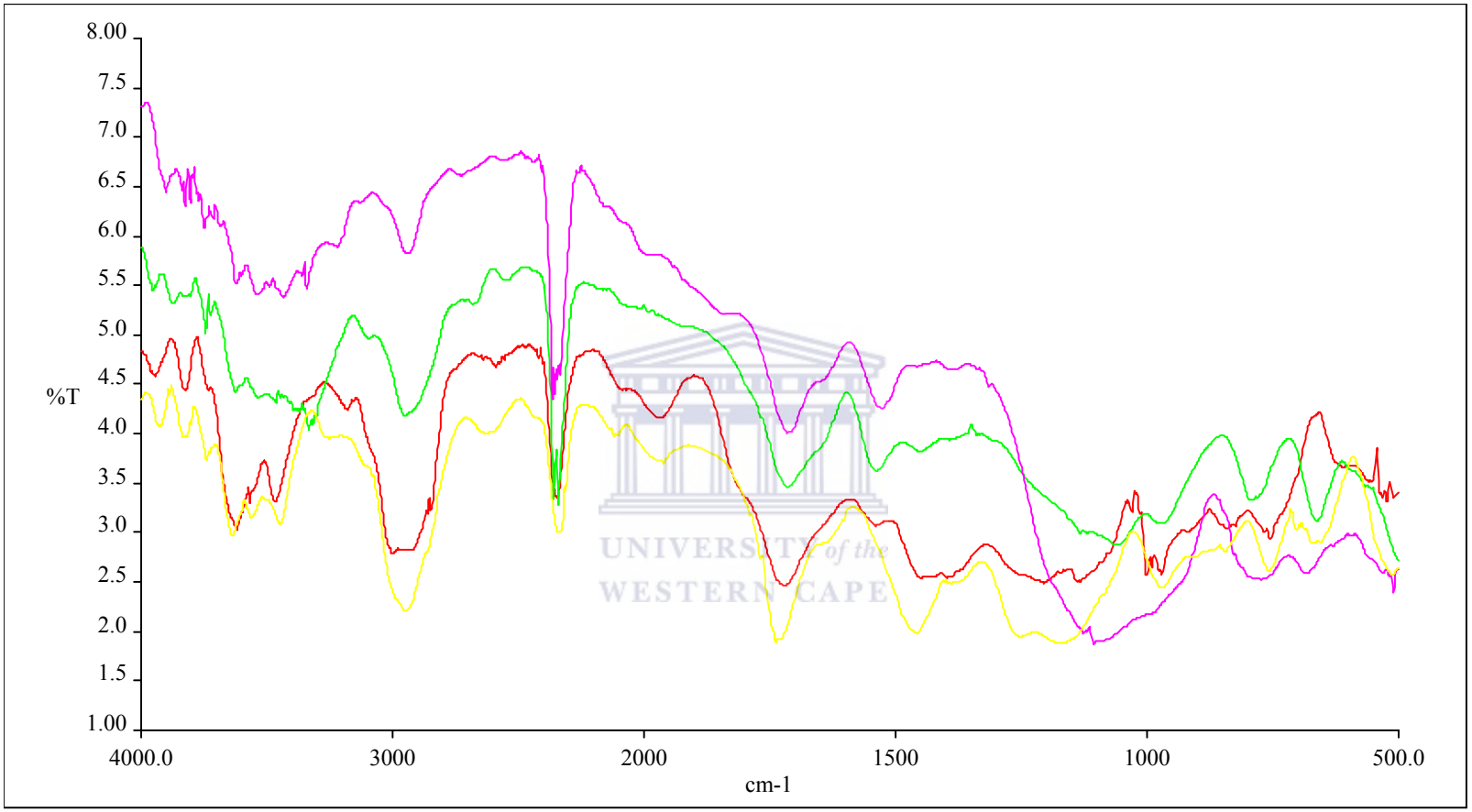
The range of the wavelengths for each component tested is from 500 - 4000 cm^{-1}.
The wavelengths for the uncured CC powder and cured CC powder are shaped similarly (as the structure is the same) but only to a point after which their particular wavelength shape differs when the structure differs (Graph 4).

When comparing the cured CC powder to the cured LC powder, some similarities are seen with regards to the peaks and valleys indicating that structurally they are similar (Graph 4).
Cross linkages could be present within each material and more could be present in the one than the other, but this is not seen with infrared spectroscopy.
The main difference between the cured CC and LC powders, indicating a difference in intensity of the wavelengths, are noted in the region of 1712 and 1730 cm^{-1} (Graph 4). The higher intensity of the wavelength (at 1730 cm^{-1}) is an indication that the quantity of molecules of a particular substance present here is very high.

When comparing the cured CC powder to the monomer, the wavelengths are very different, as the monomer structure is lost due to monomer evaporation when the material is setting (Graphs 4 and 5).

The wavelengths of the monomer on its own are very different when compared to the LC and CC materials. This is due to the presence of many other molecules, indicated as the very wavy end parts on the graph (Graph 5).

The actual identification of the structural composition and the presence of particular types of cross-linkages within each material must still be further investigated. The high performance liquid chromatography and gel permeation chromatography tests are the methods to be utilized when wanting to determine this.



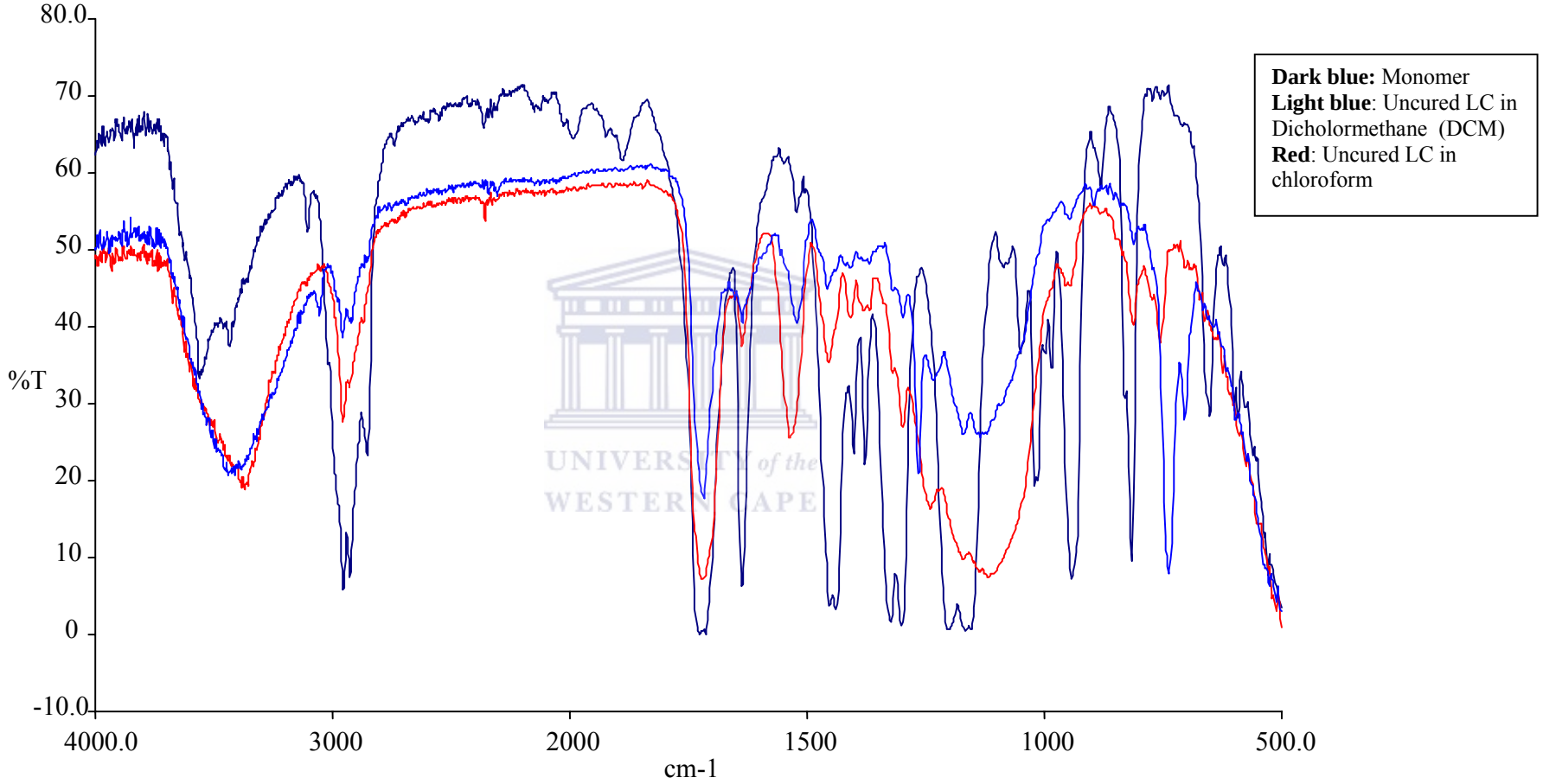
Pink: Uncured LC

Green: Cured LC powder

Red: Uncured CC

Yellow: Cured CC powder

Graph 4: Wavelengths of Uncured LC and CC acrylic resin
Wavelengths of Cured LC and CC powder



Graph 5: Wavelengths of Monomer and Uncured LC material

5.4 Survey

A total of 196 students (4th and 5th years) were found in both classes but 38 were absent on the day of the survey. One hundred and fifty eight questionnaires were distributed and returned, of which 18 did not meet the inclusion criteria and 1 person chose not to participate. Of the 139 participating students, 98 were in the 4th year and 41 in the 5th year class. The raw data are presented in Appendix 7.

With regards to gender, 85 females and 54 males participated in the survey.

In response to the question regarding which material was used often amongst the dental students, the LC acrylic resin was noted to be the more popular material (Appendix 7). Here, 77% of students indicated that they used it most often (Figure 8).

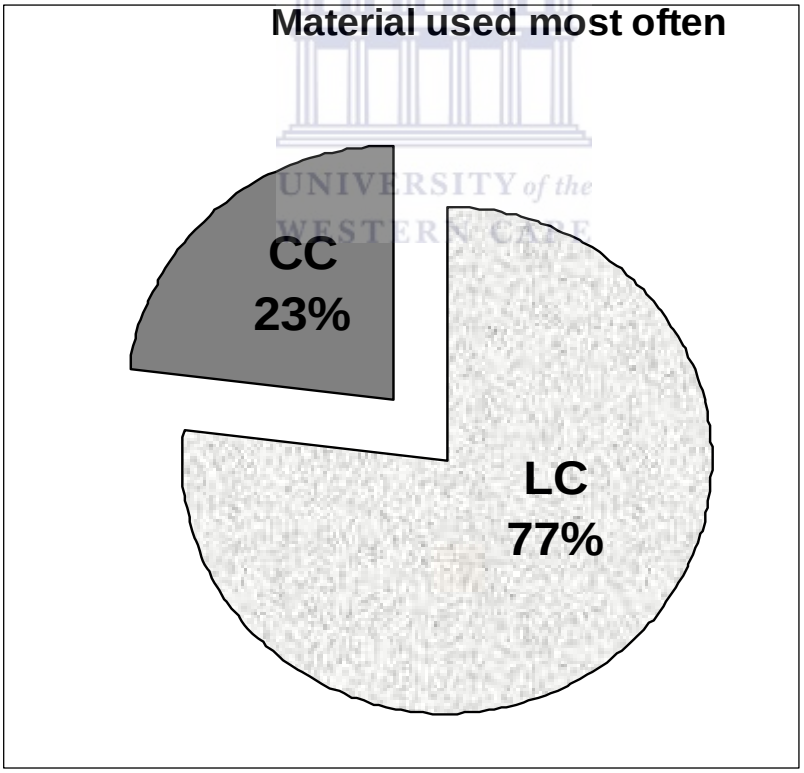


Figure 8: Material used most often by students

When asked about the ease of using either material, the students responded as follows (Appendix 7):

Ninety seven percent (response: yes and definitely yes) said that the LC acrylic resin was quicker to work with, 93% (response: yes and definitely yes) it was easier to handle and 75% it was easier to repair.

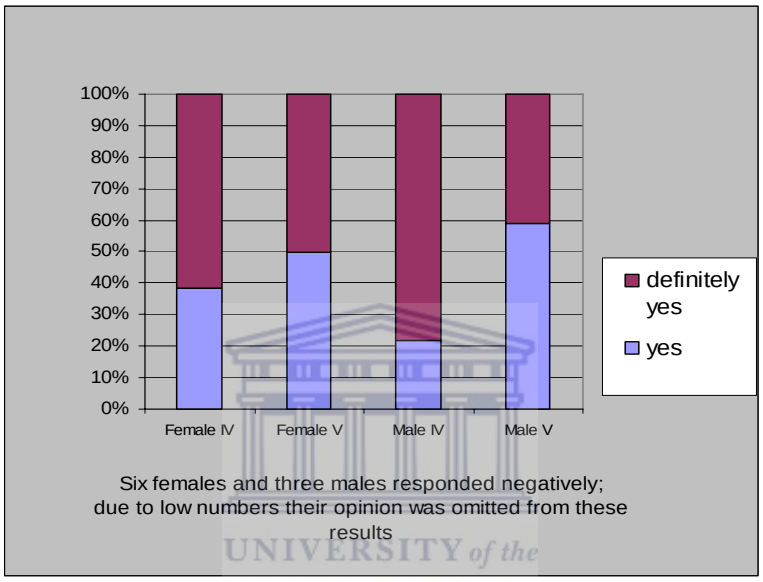


Figure 9: Ease of use of materials

Problems, as referred to in the literature were often experienced when using the CC material. Asked if they experienced the same type of problems with the CC material and if similar problems were experienced with the LC material, the students responded as follows (Appendix 7):

Seventy five percent had no time problems with the LC resin but did with the CC resin (Figure 10a).

Significantly less handling problems were associated with the LC resin (Figure 10b).

Twenty six percent had problems with the finish of the LC resin, yet 47% had no problems with the finish of either material (Figure 10c).

Problems with the odour of the CC resin were recorded at 40. 7% and only 3. 6% found that no problems were experienced with the CC resin, but they did so with the LC resin. Fifty five percent said none of the materials were problematic with regards to odour (Figure 10d).

Fig 10a) Time problems

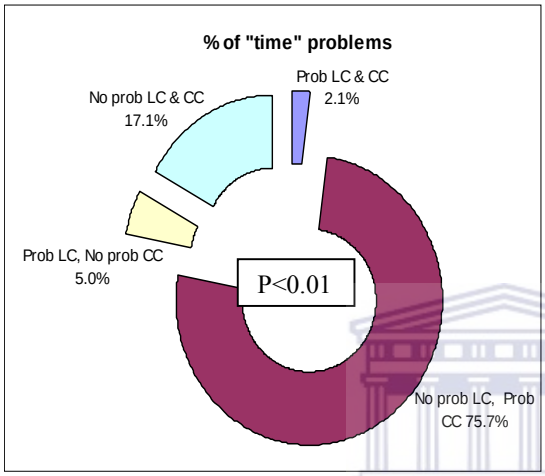


Fig 10b) Handling problems

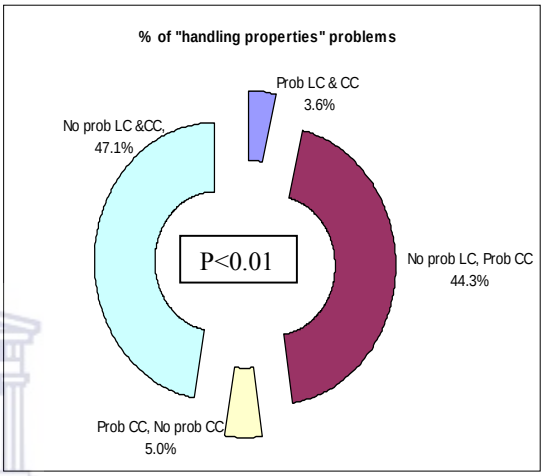


Fig 10c) Finish problems

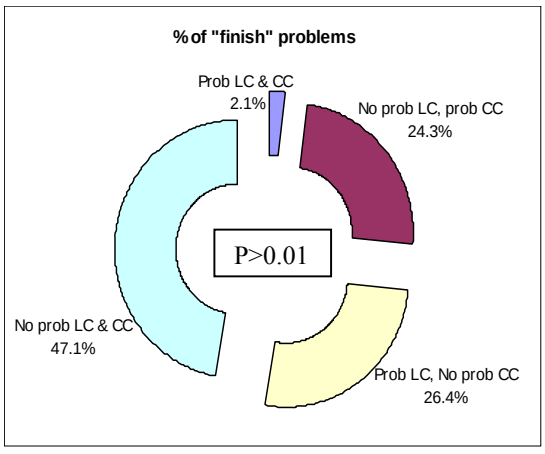


Fig 10d) Odour problems

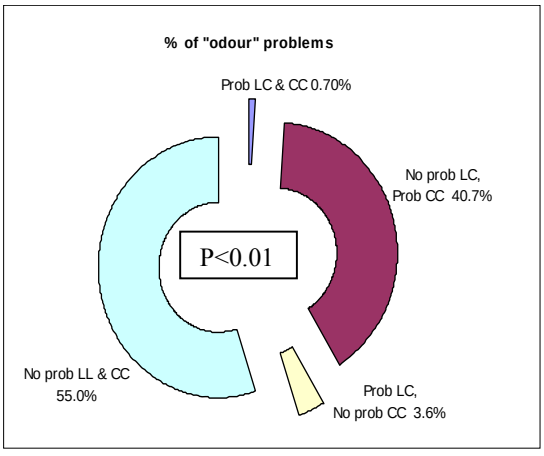


Figure 10: Problems experienced with both materials

Table 4 indicates that students had more problems with the CC than the LC resin. Three students had no problem with either material; seventeen students had one problem with both LC and CC resin and 4 students had two problems with both LC and CC resin.

Above these common problems, indicated by the shaded area, the table indicates that 111 students had more problems with CC than the LC material.

	Number of problems with CC					
Number of problems with LC	0 (No Problems)	1	2	3	4	Total
0	3	21	40	4	14	82
1		17	26	3	3	49
2		4	4			8
3	1					1
4						0
Total	4	42	70	7	17	140

Table 4: 5 x 5 cross-tabulation of the count of problems (odour, time, finishing, handling) with LC and CC acrylic resin.

There was a tendency towards the use of LC resin in both classes, although 48% of the 4th and 68% of the 5th year class inclined towards having both materials be taught and used in undergraduate training.

From the total number of participating students, 51. 6% said that both materials must be used in undergraduate training. Twenty six percent preferred the LC resin, 20% said teach and use only LC resin and no one suggested the use of CC resin exclusively as part of the curriculum (Figure 11).

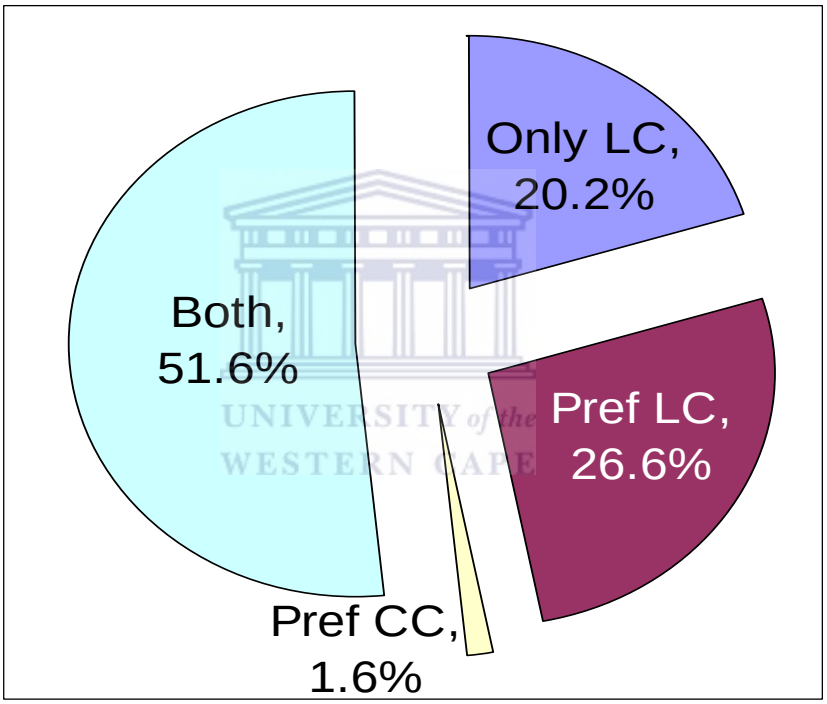


Figure 11: Material recommended by students
(Pref = preferably)

CHAPTER 6:

DISCUSSION

6.1 Introduction

In this chapter the results are analysed and compared to the existing data within the literature reviewed for this study.

Careful laboratory and clinical planning is important to the success of treatment with complete removable dentures. This includes the use of custom trays and the materials used for the construction of these trays. The properties of the custom tray materials should contribute to and ensure a successful outcome.

The literature mostly discusses the use of CC acrylic resin custom trays and its negative properties such as, lack of dimensional stability and hazardous effects of the residual monomer. More recently, some articles focussed on the properties of the LC acrylic resin for custom trays and several advantages over the CC materials have been identified. These are: lack of offensive odour; improved working time; excellent dimensional and volume stability; sufficient rigidity and stiffness; easy to work with and the immersion in disinfectants with no effect on the physical or mechanical properties of this material (Baker & Frazier, 1999 and Wirz *et al*, 1990).

This study investigated some of the properties of the CC and LC custom tray materials and compared these. Several other properties can still be investigated in the future such as flexural strength and hardness.

The dimensional stability and strength of the custom tray material was determined by measuring the linear shrinkage and fracture toughness of the LC acrylic material and comparing it to the CC type.

This study also retrospectively assessed the use and acceptance of both (LC and CC) custom tray materials amongst undergraduate dental students as no studies have been found in the literature focusing on this aspect.

6.2 Specimen fabrication

When fabricating CC specimens, correct powder and liquid ratios must be used to decrease any source of error. A vial measuring the ratio of powder to liquid (2:1) by measurement as instructed by manufacturers was used. The production of specimens resulted in a very dry and brittle specimen. This could be due to the premature evaporation of the monomer, resulting in the dryness and whitish appearance of the specimens. It could be due to the fact that small quantities of powder and liquid were mixed at a time. If the ratios were according to weight maybe the resultant specimens would not have been that dry. This can be investigated further in another study. Thus as expected, sample variance can be experienced during this stage of specimen fabrication.

The LC acrylic specimens are less technique sensitive to fabricate as this material comes in a wafer, in uniform thickness and can be cut to size in its uncured state. It is thus easier to achieve uniform samples with less distortion and sample variance is minimized. This was reflected in the results, as the standard deviation for fracture toughness was greater for the LC acrylic resin material compared to the CC resin.

A perspex template was constructed and used in this study to repeatedly produce specimens of equal dimensions (Hamza *et al*, 2004). This method is preferred to machining the specimens to the required dimensions since grinding can weaken the specimen by creating multiple cracks and surface irregularities, which can initiate the fracture process (Neihart *et al*, 1988).

6.3 Specimen storage

The storage of prepared LC and CC acrylic specimens for dimensional stability and/or fracture toughness tests has been researched and recorded in several articles, but opinions vary.

It was initially believed that by soaking the specimens in water, the linear expansion of the specimens would accommodate the initial shrinkage (Anderson *et al*, 1988). But, research has subsequently shown that the expansion does not compensate for the full extent of shrinkage (Segerström *et al*, 2005 and Anderson *et al*, 1988). Segerström *et al* (2005) revealed in his study that water storage caused expansion in width and height but not in the linear dimension.

Several articles discuss the storage of specimens (water or air), the length of storage (days or weeks) and its effect on fracture toughness. No conclusive guidelines are stipulated.

It can be concluded that even if differences in the results are seen with the water or air storage specimens, it does not significantly affect the opinions as also implied in these studies.

The decision to store the specimens in a dry or wet environment is relevant with regards to materials that are used in the oral cavity, but research has shown that fracture toughness measurement has not been affected.

The reasons for not storing the fracture toughness specimens in water are that custom trays do not function in a wet environment. The specimens for linear shrinkage measurement had to be measured immediately after fabrication according to recommended specifications. Thus it would not be of any significance if the specimens were soaked or not and that's why it was not done for both (dimensional stability and fracture toughness) tests.

For the fracture toughness test, the specimens were stored in a dry environment for 24 hours before testing ensued.

6.4 Linear shrinkage

The digital caliper was used because it is accurate, easy to use and was available. The dental (stock or custom) trays are arch-shaped and it has been reported in the literature that shrinkage of the custom trays occurs more in some areas than other areas (Rueda *et al*, 1996 and Fehling *et al*, 1986). A limitation of this study is that linear beam specimens were fabricated and only the linear shrinkage was determined.
According to the literature, linear shrinkage of the CC acrylic resin specimens was significant within the first 40 minutes, hours later in some tests, and even days later in other studies (Fehling *et al*, 1986). A time interval between fabrication and use of 30 – 40 minutes according to Stackhouse (1976) had to be allowed (cited by Fehling *et al*, 1986).

Previous studies have also alluded to the cross-arch shrinkage of CC material when using arch shaped specimens. Shrinkage of the CC material is found to be more lingual than buccal in the lower custom trays (Fehling *et al*, 1986). But according to a study by Gordon *et al* (1990), no cross-arch shrinkage was observed.

But with regards to the LC acrylic resin specimens tested in this study, this was not the situation. It was found that the LC custom tray material was dimensionally stable over time, which is in agreement with the literature (Smith *et al*, 1999 and Wirz *et al*, 1990).
The medians indicate that the immediate average shrinkage compared to the standard was significant but not the average shrinkage sequentially. The shrinkage occurs in the light-box according to some researchers and is obvious here too (Ling, 2004).
At 1440 minutes, a much lower value for median shrinkage was however measured, but no other explanation than operator error can be provided.

The minimum and maximum of any study is highly variable but on the graph it follows a particular pattern (Graph 1). The ‘dipping’ on the graph at the maximum,

third quartile and median values from 60 minutes to 1440 minutes can be viewed, but this specific pattern can't be explained (Graph 1).
The custom tray made from LC acrylic resin material can be used immediately after polymerization and no waiting period was necessary as concluded with this study too.

For a future study, cross-arch shrinkage of the LC material can be investigated as the results for cylindrical and arch-shaped test moulds for CC materials have been found to be different according to the literature (Rueda *et al*, 1996 and Fehling *et al*, 1986).

6.5 Force

The force at breakage of the LC and CC custom tray materials was determined. The CC material showed that at times no force was needed to break it (recorded as 0 in the results). This could be due to the material being very fragile/ brittle. This is an indication that there could be interference in fabrication, that is, premature monomer evaporation; vaseline applied to the template or the perspex used for the template resulting in some weak specimens.

The curve of the graph depicting force required to break these specimens is also decreasing towards the larger values, which means that the majority of forces are in the region of the smaller values. This again is an indication that the material is brittle.

In this study however, the manufacturer's instructions were followed: recommended powder and liquid ratios by measurement; in the mixing of the dough and setting of the material. The resultant variation in force resulted in a low standard deviation of the fracture toughness for the CC acrylic resin specimens.
It is common practice to add monomer to the specimens when finishing these according to Hamza *et al* (2006) and Segerström *et al* (2005), but it was not a recommendation by the manufacturers, thus not part of the fabrication protocol for this study.

The LC specimens needed more force to fracture indicating that it is stronger than the CC. This is in accordance with the literature (Smith *et al*, 1999 and Wirz *et al*, 1990).

The presence of particular constituents such as cross-linking agents could be the reason for its strength though this cannot be emphatically stated. The extreme hardness has been labeled a disadvantage by Smith *et al* (1999) as it makes it more difficult to grind although they refer to the LC material as one with 'superior mechanical properties' to all current alternatives.

6.6 Fracture toughness

Why fracture toughness determination?

As stated earlier, K_{IC} tests provide information with regards to clinical durability and are reliable for comparing different materials, as was done in this study. The tensile strength, which is derived from the flexure testing (by the three-point bend test), indirectly addresses strength by setting limits on deflection. It 'sets a minimum strength requirement, thus not discriminating materials whose strength exceeds this minimum' (Gegauff & Wilkerson, 1995). This three-point bend test is also subject to variation because of 'specimen flaws' that could be present (Hamza *et al*, 2004). This is a clear disadvantage of this 'stiffness' test (Wang *et al*, (1989) cited by Gegauff & Wilkerson, 1995).

This is bypassed by measuring the K_{IC}, where the plain strain fracture toughness/ stress intensity factor (K_{IC}) is measured (Hamza *et al*, 2004). The tensile strength and fracture toughness is not related (Gegauff & Wilkerson, 1995). A high K_{IC} is indicative of an increase in resistance to crack formation and propagation and high fracture toughness (Segerström *et al*, 2005).

This is clearly obtained and indicated with the results of the LC acrylic specimens compared to that of the CC ones that were much lower in this study (Fig 7). The range of fracture toughness values for the LC specimens was varied, but the values were still very different from the CC specimen values.

While determining K_{IC} is recommended, it cannot be used exclusively to determine the properties of a material, other tests and testing methods should be used to provide more information with regards to using that material (Bonilla *et al*, 2003). The K_{IC} values might be low for a particular material but this same material might have other superior and useful properties (Bonilla *et al*, 2003).

For example, for the application of trays, the dimensional stability and the biocompatibility are also important properties.

Why not determine the toughness of a material using the impact tests?

The impact tests are fatigue tests and are not an 'intrinsic material property' (Zappini et al, 2003). These are more time-consuming and more specimens are required to perform the test (Zappini *et al*, 2003). The impact test depends on many variables: specimen dimension; notch depth; notch radius and impact velocity as mentioned by Zappini *et al* (2003). They also alluded to the fact that there is no correlation between the impact energy measured (containing kinetic and frictional terms) and the fracture resistance property of the material itself (Zappini *et al*, 2003).

6.7 Composition analysis

Composition analysis of materials should be done as many factors within the matrix of a material affect its behavior (Jones *et al*, 1991). For example, the stress intensity (fracture toughness) is affected by the composition of the matrix of a material, be it the filler type or distribution and/or concentration of filler particles (Bonilla *et al*, 2003). This poly-methyl methacrylate matrix with its superior water absorption properties also significantly affects the fracture toughness of a material (Gegauff and Wilkerson, 1995).

By doing a full composition analyses (infrared spectroscopy, gel permeation chromatography and high performance liquid chromatography), interpretation of the spectra can provide information on the presence of cross-linking agents; the spread of molecular weight distribution; the extent of co-polymerization and its many effects on the properties of the material. This was a limitation of this study in that the presence and types of specific cross-linking agents was not determined.

The fact that the fracture toughness indicated that the LC material was stronger and needed more force to fracture, it would have been interesting to know which cross-linking agent, if any, was present and to compare that to the CC acrylic material (Figure 6).

To further increase the strength and fracture toughness of a particular material, cross-linking agents can be added to the monomer and polymer (Segerström *et al*, 2005; Arima, 1996a and Price, 1986).

6.8 Questionnaire

The use of a questionnaire as a research tool is guided by certain principles. Questions must be focused on outcomes, be unbiased and be properly sequenced. Closed questions, and questions using yes/no or definitely yes/ no answers on a scale, focus the respondents and contain the answers. This simplifies recording and analyzing of data.
A weakness of these types of questions is that no provision is made for recording any individual opinions and differences.

Ideally, in an environment with language diversity, the questionnaire should be available in all languages. Here, the questionnaire was available in two languages as it was assumed that all respondents were fluent in either one of them.

Piloting was instituted to promote clarity and eliminate any ambiguities on the questionnaire. Reliability testing, by repeating the questionnaire on a selected group within this sample, was not performed.

The survey indicated that the LC acrylic resin was used most often amongst the undergraduate students who had experience with both materials. This could be attributed to the fact that: it was considered user-friendlier by the students and /or they experienced and identified the negative effects of the CC acrylic resin and opted to use the LC acrylic material. The time taken to make custom trays with each material is also an important deciding factor; it was found to be quicker with the new LC material. This is also in accordance with the literature (Wirz *et al*, 1990). It is important to realize that this was a retrospective study and that availability of the two materials was not controlled although both LC and CC acrylic resin materials are routinely stocked at the Oral Health Centre, University of the Western Cape.

With regards to the ease of use of the LC acrylic resin:
Most respondents said it was easier to work with the LC compared to the CC acrylic resin. The focus of the students with regards to the acceptable effects of these materials was on timesaving and handling properties of both materials. It was interesting to note that timesaving with the LC acrylic was positively mentioned in the survey and this confirms the results in the literature (Wirz *et al*, 1990).

Ninety three percent (responses: yes and definitely yes) said it was easier to handle; and this was also indicated in the literature (Wirz *et al*, 1990).
Seventy five percent said that the reparability is a positive factor with the LC acrylic resin material.
The results focusing on the clinical responses could be related to following the manufacturer's instructions strictly or not. This survey makes reference to the wiping of the LC trays with a special solution (Megaclean) provided by the manufacturers. The results of the survey revealed that only 2.8% used this solution exclusively and 30% used some other agents. This is a clear indication that manufacturer's instructions were not followed closely, with the resultant low response on the clinical use of this material. The reasons why manufacturer's instructions are not followed should be investigated further.

Even though many of the articles discussed the effects of the monomer, such as emittance of vapor, as an important negative factor, only 40.7% of students alluded to this as a problem when working with this material. The absence of vapor of the LC acrylic, an advantage mentioned in the literature too, could have positively influenced the choice of this material amongst students although they did not use this as a deciding factor (Baker & Frazier, 1999 and Brown & Kerr, 1998).

The finish with the LC material was recorded as a deterrent to its use, thus it can be concluded that there are some students who do prefer to work with the CC acrylic due to the more acceptable finish.

According to the literature, the cost of the LC acrylic resin is high making it a negative factor (Wirz *et al*, 1990). What is interesting is the fact that the students recorded it as such in this survey, showing a degree of "cost-consciousness" amongst them. The increased cost is balanced by the increase in timesaving and accuracy with the use of the LC acrylic custom tray material.
With regards to the CC resin, the cost and clinical actions seem to have been the acceptable aspects as no mention was made of either as negative effects exclusively or in combination with other properties.

This survey indicated that both types of acrylic resin were acceptable as custom tray materials and no preference in teaching in this undergraduate training program was suggested.

It is important to note that with different groups within the profession such as students, dental technicians or dentists, a totally different set of results may be obtained. It depends on the amount of time spent with the materials and the exposure time to the constituents of each material as indicated in the literature too (Rajaniemi & Tola, 1985). For example, the hazardous effects will not be as clear with a person who occasionally uses the material (e.g. student) as compared to the one who uses it daily (e.g. dental technician). Therefore, a survey of this nature could be done amongst general dental practitioners /technicians and the results could be compared.

Teaching a technique course using these materials, one may have a different set of focuses and results. Students are assessed according to their handling of the materials, of the instrumentation and equipment involved and the outcome of the final product. When using the LC acrylic resin, which comes in a wafer /sheet and can be cut to size, opportunities of assessing dexterity and managing of the material are lost.

Thus from a teaching perspective, using the CC acrylic resin would provide one with more criteria to assess the practical abilities of dental students.

The null hypotheses for all three tests:

- linear shrinkage
- fracture toughness and
- ‘user-friendliness’

of the LC acrylic resin material, compared to the CC acrylic resin material, in this study were rejected.

CHAPTER 7

CONCLUSIONS

This chapter presents the conclusions drawn from the results of this research. In research where so many variables have to be considered, many minor changes to these variables can be implemented for future studies. These recommendations are also stipulated in this chapter.

7.1 Conclusions

1. Significant linear shrinkage of the LC acrylic resin occurs during polymerization. Thereafter, a steady but insignificant decrease in linear dimension of the specimen takes place over time. Thus, custom trays made from this material may be used immediately after polymerization.

2. The force needed to fracture LC and CC acrylic specimens differs significantly, with the LC acrylic being the stronger material.

3. The resultant fracture toughness is significantly higher for the LC acrylic specimens compared to the CC ones. These LC specimens are stronger and are thus a viable alternative to the CC specimens.

4. Most undergraduate dental students positively accepted the light-cured acrylic resin material, but training in the use of both materials was suggested.

5. A dental school should not experience any difficulty and/ or resistance in teaching the use of LC acrylic resin for custom trays. The inclusion of both types of materials in the curriculum provides students with increased training opportunities.

7.2 Recommendations for future research

a) Test **adhesion** of impression material in the LC tray compared to CC material.

b) Determine the **hardness** of LC and CC acrylic resin specimens and compare the two results.

c) Determine the **flexural strength** (resistance to bending) of the LC and CC acrylic resin specimens and compare the results.

d) Determine actual cross - linking agents using gel permeation chromatography and high performance liquid chromatography - do the **DMA i.e. the composition analysis.**

e) **Add different cross-linking agents** (and at different percentages) to the material i.e. to the monomer/ polymer and then test for fracture toughness and determine which agent is stronger. Segerstrom *et al*, (2005) and Arima *et al*, (1996a) indicated that mechanical properties can be changed by choice of cross-linking agents and its addition improves craze resistance and hardness.

f) A **survey** could be done to determine types of custom tray materials used and their acceptability amongst general dental practitioners /dental technicians. Results can be compared.

g) Dental schools should perform research into newer materials and serve as a guide to changes in their use. It should not be left to dental companies alone.

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A P P E N D I C E S

APPENDIX 1

OFFICE OF THE DEAN
DEPARTMENT OF RESEARCH
DEVELOPMENT

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16 May 2007

To Whom It May Concern

I hereby certify that the Senate Research Committee together with the relevant Ethics Committee of the University of the Western Cape has approved the methodology and the ethics of the following projects by: Dr. S Khan

Research Project: Mechanical and handling properties of light-cured acrylic resin tray material

Registration number: 06/3/9

Refgt Syster
Research Development
University of the Western Cape

APPENDIX 2

TO; TYGERBERG ORAL HEALTH CENTRE 9 February 2006
DEPARTMENT OF PROSTHETICS
ATTENTION: DR KHAN

Dear Dr Khan,

This letter serves as confirmation that I, Ralf Schulz acknowledge that dental materials and goods were donated to the department.

We do not have any expectations with regards to the findings on your research as goods were donated as a gesture of goodwill.

Please do not hesitate to contact our offices for any further enquiries regarding the above.

Many Thanks

RALF SCHULZ
DIRECTOR

1 Nerina Street Mllnerton 7441 Cape Town - 8001 - South Africa - Reg No. 1962/03910/07
Tet; +27 21 552 272V06 - Fax: +27 21551 5311. - mailto:megadent@'taWca.com

APPENDIX 3

SURVEY OF CUSTOM TRAY CONSTRUCTION FOR REMOVABLE COMPLETE DENTURES

This is a study conducted in the Department of Prosthetics amongst dental students.
Your co-operation is completely voluntary.
Anonymity is guaranteed.

CONDITIONS OF THE STUDY :

The student must be a **IVth** year or **Vth** year undergraduate dental student.
The student must have used **both** auto polymerizing and light-curing acrylic resin cutom tray material in their training.
The trays must have been constructed for **complete denture**s only.

INSTRUCTIONS TO RESPONDENTS :

Please answer all the questions.

Cross your responses clearly.
At the bottom of the questionnaire, fill in the boxes with regards to **gender** and **year of study.**

Read conditions and/or questions carefully.

Do not write any other comments.

Thank you for your kind co-operation.

Dr. S. Khan

PS: You will be informed of the outcome of this study

3.1. Questionnaire:

1	**When constructing a custom tray for complete dentures, which material did you use most often?**	light-cured custom tray material	chemically-cured custom tray material

2	**Light-cured material is quicker to work with than the chemically-cured material.**	definitely no	no	yes	definitely yes
3	**Light-cured material is easier to handle than chemically-cured material**	definitely no	no	yes	definitely yes
4	**It is easier to repair the light-cured tray than the chemically-cured tray**	definitely no	no	yes	definitely yes
5	**It is easier to add impression compound / Greenstick for border molding to the light-cured than the chemically-cured tray.**	definitely no	no	yes	definitely yes
6	**S-S white impression material bonds/adheres better to the light-cured than the chemically-cured trays**	definitely no	no	yes	definitely yes

7	**Did you use anything to wipe or clean the light-cured special tray with?**	yes	no			
8	**If so, what did you use? (You can mark more than one option)**	water	monomer	Megaclean	soap	Other

9	**What negative effects would deter you from using <u>chemically-cured resin</u> for custom tray construction? (you can mark more than one option)**	odour	finish	time	Handling properties
10	**What negative effects would deter you from using <u>light-cured resin</u> for custom tray construction? (you can mark more than one option)**	odour	finish	time	Handling properties

11	**What would you recommend be taught and used in the Dental School?**	only light-cured	preferably light-cured	preferably chemically-cured	only chemically-cured	both

3.2. Questionnaire (Afrikaans):

1	**Wanneer jy spesiale lepels gemaak het vir volledige kunsgebitte, watter materiaal het jy mees dikwels gebruik?**	lig-kuur akriel	chemies-kuur akriel

2	**Lig-kuur akriel is vinniger om mee te werk as chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
3	**Lig-kuur akriel hanteer makliker as chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
4	**Lig-kuur akriel is meer esteties aanvaarbaar as chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
5	**Lig-kuur akriel poleer makliker as chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
6	**Dit is makliker om 'n lepel vervaardig van lig-kuur akriel te herstel as 'n lepel van chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
7	**Dit is makliker om afdruk-kompo/Greenstick (vir "border moulding") te heg aan lig-kuur akriel as aan chemies-kuur akriel**	nee, beslis nie	nee	Ja	ja, beslis
8	**S-S white afdrukmateriaal bind/heg beter aan lig-kuur materiaal as aan chemies-kuur material**	nee, beslis nie	nee	Ja	ja, beslis

9	**Het jy iets gebruik om die lig-kuur lepel mee af te vee of skoon te maak?**	ja	Nee			
10	**Indien wel, wat het jy gebruik? (jy kan meer as een opsie uitoefen)**	water	monomeer	Mega clean	Seep	Iets anders

11	**Watter negatiewe aspekte van die <u>chemies</u>-kuur materiaal sal jou keer om dit weer te gebruik vir spesiale lepels? (jy kan meer as een opsie uitoefen)**	geur	Afwerking	tyd	kliniese werking	koste	Hanterings eien-skappe
12	**Watter negatiewe aspekte van die <u>lig</u>-kuur materiaal sal jou keer om dit weer te gebruik vir spesiale lepels? (jy kan meer as een opsie uitoefen)**	geur	Afwerking	tyd	kliniese werking	koste	Hanterings eien-skappe

13	**Wat sal jy aanbeveel moet aangeleer word in die Tandheelkunde Fakulteit?**	slegs ligkuur	verkieslik lig-kuur	verkieslik chemies-kuur	slegs chemies-kuur	albei

Geslag	M	V
Studiejaar	IV	V

APPENDIX 4

Average length in mm of the LC acrylic specimens at different time intervals

Specimen ID	30 min	60 min	1440 min	2160 min	2880 min
1	19.56	19.51	19.6	19.57	19.53
2	19.72	19.67	19.79	19.66	19.62
3	19.72	19.72	19.8	19.76	19.72
4	19.74	19.68	19.8	19.79	19.72
5	19.77	19.68	19.83	19.79	19.72
6	19.72	19.72	19.78	19.76	19.7
7	19.77	19.72	19.81	19.79	19.73
8	19.74	19.72	19.79	19.78	19.73
9	19.77	19.74	19.83	19.79	19.76
10	19.77	19.74	19.81	19.73	19.71
11	19.77	19.77	19.8	19.74	19.73
12	19.84	19.77	19.77	19.77	19.75
13	19.8	19.82	19.71	19.7	19.69
14	19.74	19.78	19.79	19.73	19.71
15	19.74	19.81	19.81	19.69	19.69
16	19.81	19.86	19.8	19.71	19.73
17	19.82	19.84	19.8	19.71	19.7
18	19.8	19.82	19.78	19.71	19.69
19	19.83	19.84	19.83	19.74	19.73
20	19.83	19.82	19.82	19.72	19.72

APPENDIX 5

Table of LC specimen data used to calculate the Stress Intensity (Fracture toughness)

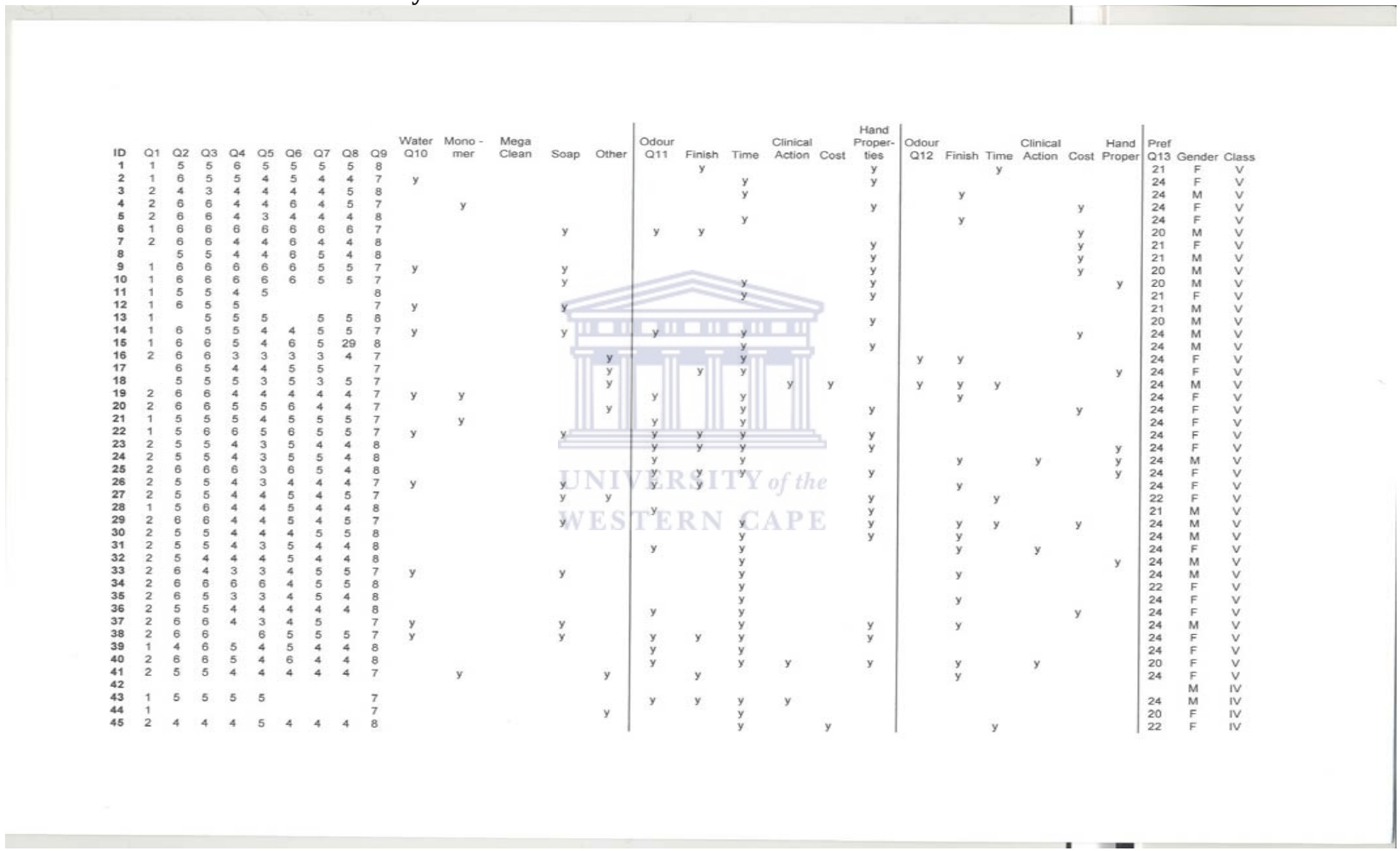
Specimen ID	Type	a (crack l)	w (width)	b (thickness)	L (distance)	P (Force)	Kic (fin)
1	LC	3	4.2	2	17	8.65	53.80959
2	LC	3	4.2	2	17	3.45	21.46163
3	LC	3	4.2	2	17	6.11	38.00885
4	LC	3	4.2	2	17	17.01	105.8152
5	LC	3	4.2	2	17	12.01	74.71135
6	LC	3	4.2	2	17	11.4	70.91668
7	LC	3	4.2	2	17	4.07	25.3185
8	LC	3	4.2	2	17	12.78	
9	LC	3	4.2	2	17	9.33	58.0397
10	LC	3	4.2	2	17	15.29	95.11544
11	LC	3	4.2	2	17	9.61	59.78152
12	LC	3	4.2	2	17	7.61	47.33999
13	LC	3	4.2	2	17	8.83	54.92932
14	LC	3	4.2	2	17	11.91	74.08927
15	LC	3	4.2	2	17	13.6	84.60236
16	LC	3	4.2	2	17	14.13	87.89936
17	LC	3	4.2	2	17	13.54	84.22911
18	LC	3	4.2	2	17	10.28	63.94943
19	LC	3	4.2	2	17	8.64	53.74738
20	LC	3	4.2	2	17	12.79	79.56354

APPENDIX 6

Table of CC specimen data used to calculate the Stress Intensity (Fracture toughness)

Specimen ID	Type	a (crack l)	w (width)	b (thickness)	L (distance)	P (Force)	Kic (fin)
1	CC	3	4.2	2	17	0.37	2.301682
2	CC	3	4.2	2	17	0.7	4.354533
3	CC	3	4.2	2	17	1.52	9.455557
4	CC	3	4.2	2	17	0	0
5	CC	3	4.2	2	17	2.06	12.81477
6	CC	3	4.2	2	17	0	0
7	CC	3	4.2	2	17	1.03	6.407384
8	CC	3	4.2	2	17	0.5	3.110381
9	CC	3	4.2	2	17	1.1	6.842838
10	CC	3	4.2	2	17	1.21	7.527121
11	CC	3	4.2	2	17	1.15	7.153876
12	CC	3	4.2	2	17	1.6	9.953218
13	CC	3	4.2	2	17	1.09	6.78063
14	CC	3	4.2	2	17	1.77	11.01075
15	CC	3	4.2	2	17	1.46	9.082312
16	CC	3	4.2	2	17	1.96	12.19269
17	CC	3	4.2	2	17	1.97	12.2549
18	CC	3	4.2	2	17	2.79	17.35592
19	CC	3	4.2	2	17	0	0
20	CC	3	4.2	2	17	0	0

APPENDIX 7: Raw Data 1 of Survey



ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Water Q10	Mono - mer	Mega Clean	Soap	Other	Odour Q11	Finish	Time	Clinical Action	Cost	Hand Proper-ties	Odour Q12	Finish	Time	Clinical Action	Cost	Hand Proper	Pref Q13	Gender	Class
1	1	5	5	6	5	5	5	5	8							y				y			y				21	F	V
2	1	6	5	5	4	5	4	4	7	y							y			y							24	F	V
3	2	4	3	4	4	4	4	5	8								y					y					24	M	V
4	2	6	6	4	4	6	4	5	7		y									y					y		24	F	V
5	2	6	6	4	3	4	4	4	8								y					y					24	F	V
6	1	6	6	6	6	6	6	6	7				y		y	y									y		20	M	V
7	2	6	6	4	4	6	4	4	8											y					y		21	F	V
8		5	5	4	4	6	5	4	8											y					y		21	M	V
9	1	6	6	6	6	6	5	5	7	y			y							y					y		20	M	V
10	1	6	6	6	6	6	5	5	7				y				y			y						y	20	M	V
11	1	5	5	4	5				8								y			y							21	F	V
12	1	6	5	5					7	y			y														21	M	V
13	1		5	5	5		5	5	8											y							20	M	V
14	1	6	5	5	4	4	5	5	7	y			y		y		y								y		24	M	V
15	1	6	6	5	4	6	5	29	8								y			y							24	M	V
16	2	6	6	3	3	3	3	4	7					y			y				y	y					24	F	V
17		6	5	4	4	5	5		7					y		y	y									y	24	F	V
18		5	5	5	3	5	3	5	7					y				y	y		y	y	y				24	M	V
19	2	6	6	4	4	4	4	4	7	y	y				y		y					y					24	F	V
20	2	6	6	5	5	6	4	4	7					y			y			y					y		24	F	V
21	1	5	5	5	4	5	5	5	7		y				y		y										24	F	V
22	1	5	6	6	5	6	5	5	7	y			y		y	y	y			y							24	F	V
23	2	5	5	4	3	5	4	4	8						y	y	y			y						y	24	F	V
24	2	5	5	4	3	5	5	4	8						y		y					y		y		y	24	M	V
25	2	6	6	6	3	6	5	4	8						y	y	y			y						y	24	F	V
26	2	5	5	4	3	4	4	4	7	y			y		y	y						y					24	F	V
27	2	5	5	4	4	5	4	5	7				y	y						y			y				22	F	V
28	1	5	6	4	4	5	4	4	8						y					y							21	M	V
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30	2	5	5	4	4	4	5	5	8								y			y		y	y				24	M	V
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32	2	5	4	4	4	5	4	4	8								y					y		y			24	M	V
33	2	6	4	3	3	4	5	5	7	y			y				y					y					24	M	V
34	2	6	6	6	6	4	5	5	8								y										22	F	V
35	2	6	5	3	3	4	5	4	8								y					y					24	F	V
36	2	5	5	4	4	4	4	4	8						y		y								y		24	F	V
37	2	6	6	4	3	4	5		7	y			y				y			y		y					24	M	V
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40	2	6	6	5	4	6	4	4	8						y		y	y		y		y		y			20	F	V
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42																												M	IV
43	1	5	5	5	5				7						y	y	y	y									24	M	IV
44	1								7					y			y										20	F	IV
45	2	4	4	4	5	4	4	4	8								y		y				y				22	F	IV

Data2

Data3

94	1	6	6	6	6	6	5	6	7				y	y	y	y	y			y					y		21	F	IV
95	1	6	6	4	4	3	5	5	7				y			y	y								y		21	F	IV
96	2	5	4	5	3	5	5	4	7					y	y	y	y							y		y	21	F	IV
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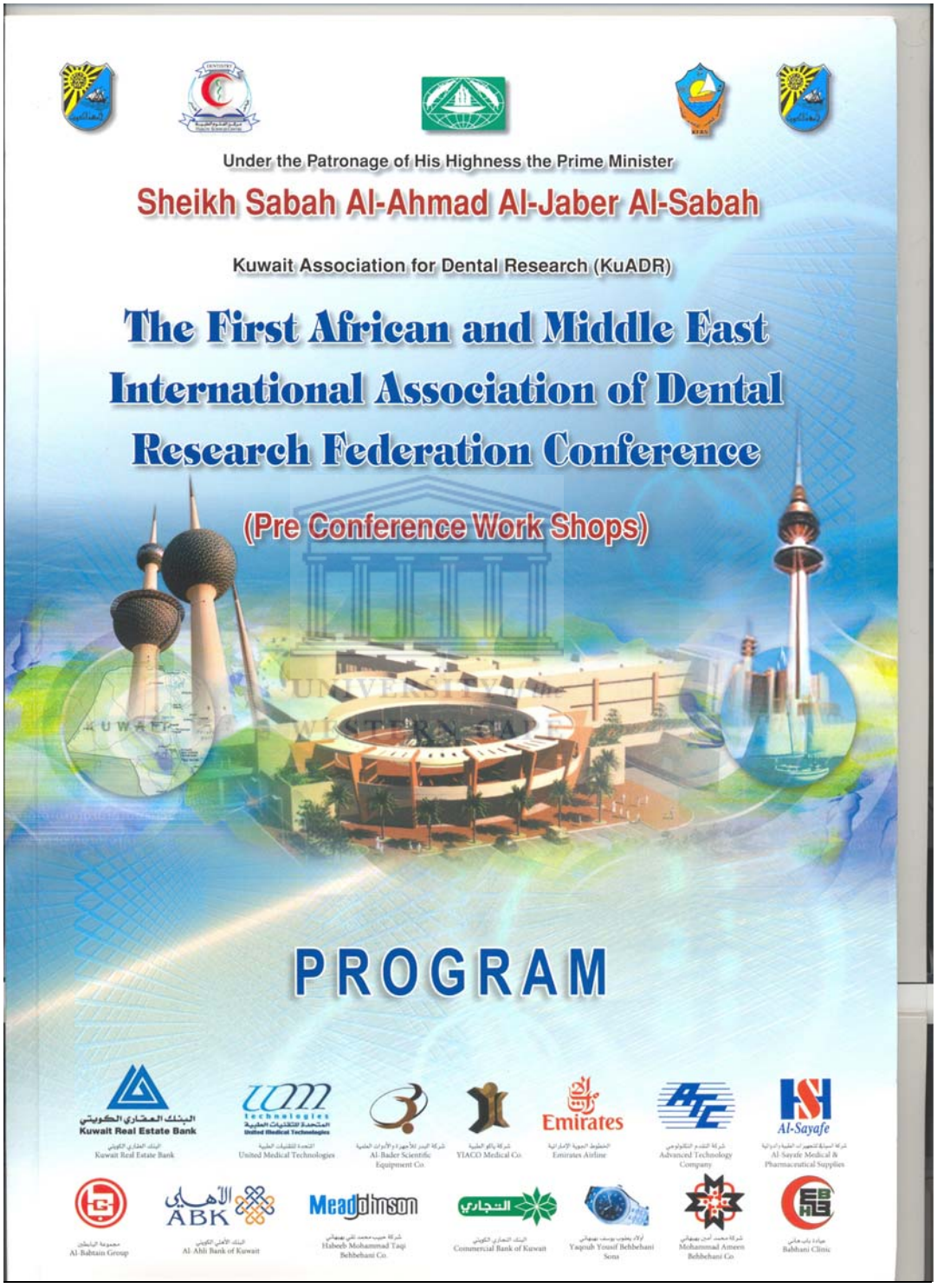
139	1	5	5	4	4	4	4	4	7	y				y	y		y								y		24	F	IV
140	1	6	5	5	4	5	5	5	7		y		y				y			y						y	24	F	IV

APPENDIX 8


Under the Patronage of His Highness the Prime Minister
Sheikh Sabah Al-Ahmad Al-Jaber Al-Sabah
Kuwait Association for Dental Research (KuADR)
The First African and Middle East International Association of Dental Research Federation Conference
(Pre Conference Work Shops)
PROGRAM
Kuwait Real Estate Bank
United Medical Technologies
Emirates
Al-Sayafe
ABK
Meadjohnson
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96. DR 69186: BiocompatibiSity of Two Orthodontic Alloys in Rat Subcutaneous Connective Tissue
S. SADEGHIAN BOROUJENI. and A. MASAELY, Azad Khorasgan University Dental School, Isfahan, Iran.

97. **DR 69689: Acceptance of Light-Curing Acrylic Resin Tray Material by Dental Students**
S. KHAN. and G. GEERTS, University of the Western Cape, Cape Town, South Africa.

CARIOLOGY & PROSTHETIC DENTISTRY & IMPLANTS:

98. DR 69727: Dental Caries among a Ugandan Rural Population
C. RWENYOIMYI1, L. MUWAZI2, and W. BUWEMBO3, 1 Makerere University, Kampala, Uganda, 2 Mulago Hospital, Kampala, Uganda, 3 Marmara University, Kampala, Uganda.

99. DR 69452: Comparative Evaluation of Conservative Management of Dentine Hypersensitivity
C.T.BAMISE^A.O. OLUSILE1, A. 0. OGINNI1, and 0.0. DOSUMU2, 1 Obafemi Awolowo University, lle-ife, Osun state, Nigeria, 2 University of Ibadan, Nigeria.

100. DR 68848: Strength of Incisors Restored by Metallic, Fiber and Ceramic Posts
E. AMINSALEHl AI-Badar Rural Dental College & Hospital, Tehran, Iran.

101. DR 69602: Effect of Vital Bleaching on the Flexural Strength of Teeth
H. AMERi. M. GHAVAMNASIRI, and S. ABEDINi, Mashad Dental School, Iran.

102. DR 66341: Effect of Type of Fiber on Flexural Strength of Composite
A. GHASEMI, Shahid Beheshti University, Theran, Iran.

103. DR 69243: Dental Treatment Under General Aneasthesia at a Nairobi Children's Hospital
M. MASIGA. Nairobi Dental School, Kenya.

104. DR 68849: Comparison of Apical Leakage Patterns Shown by Two Different Methods
J. MODARESI. University of Yazd, Iran.

105. DR 67565: Atraumatic Restorative Treatment (ART): the Tanzanian Experience
G.J. MANDARi. and M.I. MATEE, Muhimbili University College of Health Sciences, Dar es salaam, Tanzania.

106. DR 66993: Prothodontic-Treatment Awareness among Elderly Patients Attending Dental Clinics in Dar-Es-Salaam
B.A. MBOGO1. E.N. KIKWILU1. and D.B. KILASARA2, Muhimbili University College of Health Sciences, Dar es Salaam, Tanzania, 2 Muhimbili National Hospital, Dar es Salaam, Tanzania.

APPENDIX 9

THE USE OF LIGHT-CURING ACRYLIC RESIN SPECIAL TRAYS BY UNDERGRADUATE DENTAL STUDENTS.

S KHAN*, GAVM GEERTS. University of the Western Cape

Statement of the problem

Literature doesn't indicate which features of chemically-curing (CC) or light-curing (LC) acrylic resin for special trays contribute to it's user-friendliness or preference of use in a training environment.

Aims

1. To identify which material is used most often by dental students
2. To determine ease of use of both materials
3. To determine aspects of both materials that are most unacceptable to students
4. To ascertain recommendations by students which material should be taught and used in undergraduate training.

Method and Materials

A questionnaire **(fig 1)** was distributed amongst the IVth and Vth year dental students (n=196). Only students who had experience with both CC and LC acrylic resin **(fig 2a & 2b)** were included in the survey. The data were entered and analysed by means of Chi-Square tests. Crosstabulations were conducted and significance of differences in preference was determined by McNemer tests.

Fig 1

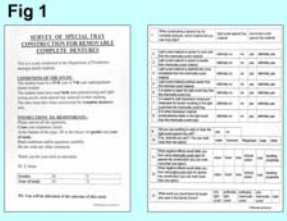


Fig 2a

Fig 2b

Fig 3. Material used most often

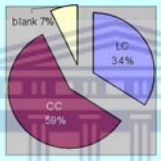


Fig 4. Ease of use

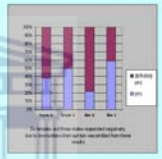


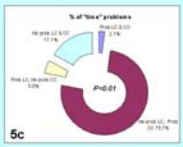
Fig 5. 5-by-5 cross tabulation of some of the negative effects (odour, time, finishing, handling) of LC and CC resin

Number of problems with LC	Number of problems with CC: 0 (No Problems)	1	2	3	4	Total
0	3	21	40	4	14	82
1		17	26	3	3	49
2			4	4		8
3	1					1
4						0
Total	4	42	70	7	17	140

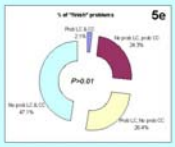
5a

111 students had more problems with CC than LC
5 students had less problems with CC than LC

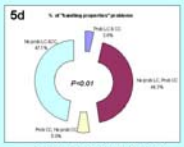
5b



5c



5e



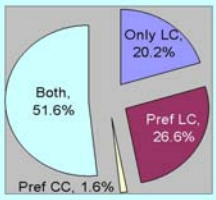
5d

P<0.01 is statistically significant

Results

139 questionnaires were retrieved from IVth (n=98) and Vth (n=41) year students. Students used the LC resin most often (77%). **(fig 3)** 93 % said that it was easier to handle. **(fig 4)** Some problems experienced are represented in **fig 5a**. 41% had a problem with the odour of the CC resin. **(fig 5b)** 75% had no time problem with the LC resin. **(fig 5c)** There was significantly less handling problems with LC resin. **(fig 5d)** 26% had problems with the finish of the LC resin, yet 47% had no problems with the finish of either LC or CC resin. **(fig 5e)** There was a tendency towards the LC resin in both classes, although 48% of the IVth yr and 68% of the Vth yr class (total: 52%) preferred that both materials be used and taught in undergraduate training. **(fig 6)**

Fig 6. Material to be recommended



Conclusion

Most undergraduate students positively accepted the light-curing material, but training in the use of both materials was still suggested.

Acknowledgements: Prof R Lalloo and Dr T Kotzé for their assistance in the data analysis.

APPENDIX 10

Program for IADR 2006 in Pretoria.

Thursday 7 September 2006 12:30 Poster Viewing Session: Acropolis 4		
	64	**U. Chikte*, S.R. Grobler, A. Louw** Accuracy of drinking water fluoride concentrations in South Africa
	65	**I. Du Preez*, T. Oberholzer, J. Olivier *et al.*** Visual, microscopic, tactile and radiographic identification of occlusal caries
	66	**S. Grobler*, A. Louw, R. Rossouw, U. Chikte, N. Basson** Bone density, fluorosis and fluoride concentration in drinking water
		Thursday 7 September 2006 (Session 7 continued):
	67	**T.S. Gugushe** Variables that impact on the treatment modalities of dentists
	68	**A.J. Louw*, I.Sarvan, U.M.E.Chikte** Three year clinical performance of ART and MIT restorations
	69	**A. Majeed*, Y. Osman, S.R. Grobler, R. Rahbeeni, H. Moola** Spectrophotometric evaluation of color reproduction by dental laboratories at UWC
	70	**S.M. Nemutandani*, S. Mickenautsch, V. Yengopal, *et al.*** Patient comfort after chemo-mechanical caries removal – a systematic review
	71	**M. Makofane*, T. Oberholzer, I. Du Preez** Intra-pulpal temperature changes induced by halogen and lead curing units
	72	**E. Pitout*, T. Oberholzer, I. Du Preez** In vivo evaluation of minimal-invasive and non-invasive direct veneer techniques
	73	**S. Shaygh** A prospective clinical study of implants (four years)
	74	**J. Wanjau** Effects of ART on oro-facial manifestations of HIV/AIDS in children
	75	**J.G. White*, C. Krüger, W. Snyman** Development of a curriculum in relational communication skills
	76	**V. Yengopal*, S. Mickenautsch, S. Leal, A.C. Bezerra, V. Cruvinel** Casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) – a systematic review
	77	**S. Tootla** Clinical success of EndoRez as an obturation material – a case study
	78	**S. Setzer, H. Dullabh, R. Sindhu*, A. Hira** Amelogenesis imperfecta and enamel hypoplasia in a 12 year old boy
	79	**Y. Malele*, V. Yengopal, M. Rudolph, T. Cohen** Patient satisfaction in Johannesburg Metro Oral Health Services (JMOHS)
		Dental materials posters
	80	**S. Ismail*, S. Grobler** An investigation into factors affecting microleakage determination of dental restorations
	81	**S. Khan*, G. Geerts** Dimensional stability of light-cured acrylic resin special tray material
	82	**R. Lombard*, I Du Preez, T. Oberholzer** Microleakage of bonded amalgams: butt joint versus internal bevel preparations
	83	**T. Oberholzer*, E. Pitout** Testing methods to determine sealing ability of root filling materials
13:00		**Lunch/Trade Exhibition** — **Acropolis 1**

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APPENDIX 11

Poster presentation at IADR 2006 in Pretoria.

DIMENSIONAL STABILITY OF LIGHT - CURED ACRYLIC RESIN SPECIAL TRAY MATERIAL

KHAN SB, GEERTS GAVM*. University of the Western Cape

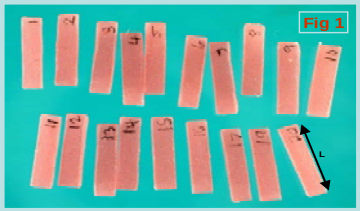
OBJECTIVE

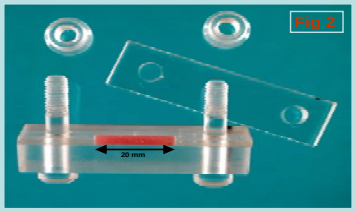
To determine the linear dimensional shrinkage of light-cured (LC) acrylic resin special tray material stored in a dry environment.

METHOD

Twenty LC acrylic resin** specimens **(Fig 1)** with configurations of 2 x 4.2 x 20mm as set out in the guidelines of the American Society for Testing Materials were fabricated using a custom-made perspex template **(Fig 2)**. The length of the template (20mm) served as the standard to compare dimensional changes. The specimens were cured in a light-polymerizing unit for 3 minutes. Thereafter, the specimens were removed from the template and placed in the curing unit again for 3 minutes to ensure complete polymerization. The length (L) of the specimens was measured 3 times at: 30 minutes, 1 hour, 24, 36 and 48 hours following polymerization, using a digital Vernier gauge. The values at each time interval were recorded. The mean, median and interquartile ranges of the shrinkages from the standard of 20mm were calculated. The Wilcoxon Signed Rank test was used to evaluate the extent of shrinkage over time. A p-value of less than 0.05 was considered to be significant.

**Megatray®, Megadent, Radeberg, Germany



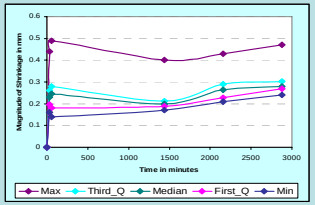


RESULTS

The values (in mm) of the median, minimum, maximum, first and third quartiles of the shrinkage recorded at the different time intervals are shown in **Table I**. According to the Wilcoxon Signed Rank test, shrinkages at all the different time intervals were highly significant compared to the standard ($p<0.05$). With reference to the median, an increase in shrinkage over time was noted. However, the changes in shrinkage between the different time intervals were not significantly different ($p>0.05$). The values in table I are displayed on **Graph I**.

Minutes / Shrinkage	0	30	60	1440	2160	2880
Max	0	0.440	0.490	0.400	0.430	0.470
Third Q	0	0.260	0.280	0.212	0.290	0.302
Median	0	0.230	0.245	0.200	0.265	0.280
First Q	0	0.198	0.180	0.190	0.227	0.270
Min	0	0.160	0.140	0.170	0.210	0.240

Table I



Graph I

CONCLUSIONS

The results show that significant linear shrinkage occurs immediately. Thereafter, a steady but insignificant decrease in dimension of the specimen takes place over time. Thus, special trays made from this material may be used immediately after polymerization.

Acknowledgements: Dr Theuns Kotze for his assistance in the data analysis.