THE STRENGTH OF PROVISIONAL CROWN AND FIXED PARTIAL DENTURE (BRIDGE) MATERIALS

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B.Ch.D. (U.W.C.)

A study to compare the strength of various provisional crown and fixed partial denture materials.

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Date Submitted: 29th February 1988

DEDICATION

This is dedicated to my mother, father, wife Fawzia and children Ayesha, Muhammad and Fatima who each in their own way made it possible.

DECLARATION

I declare that "The study to compare the strength of various provisional crown and fixed partial denture (bridge) materials" is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of completed references.

Signed : .....

Y.I. OSMAN

ACKNOWLEDGEMENTS

Dr. C. Jooste, University of Stellenbosch, for initially suggesting this study and for continually being available during the experiments.

The University of Stellenbosch for allowing me to use their facilities for the experiments.

Dr. C.P. Owen for reading and re-reading the manuscript. His advice was always constructive and most beneficial.

Prof. R.J.C. Wilding for his advice and support both as chairman of the research committee and as a friend.

Dr. V. Joseph and Dr. M. Ferguson for all the time they spent with me on the computer.

Mr. Prins from the Instrument Workshop of the University of the Western Cape for making the brass mould which was used in the manufacturing of all the specimens required in the experiments.

Mr. Orme and the laboratory assistants for making the heat-cured, laboratory processed specimens.

Prof. Knoesen and Mr. Julies of the Physics Department of the University of the Western Cape who so willingly helped with the scanning electron microscope.

Yolanda Erasmus for having typed the original draft of this dissertation and to anyone else I may have overlooked thank you very much.

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CHAPTER 1 : INTRODUCTION

Provisional crown and fixed partial denture (bridge) materials are often referred to as "temporary" materials. The Oxford Dictionary defines temporary as "lasting, or meant to last only for a time; not permanent". Yet for crown and fixed partial denture restorations a provisional restoration is crucial to the final restoration. It is, or should be, a preview of the final prosthesis.

The failure of many a fixed restoration may be directly or indirectly related to the incorrect selection of a provisional restorative material which has inadequate properties combined with incorrect manipulation. The provisional restoration remains fixed in the mouth while the permanent restoration is being fabricated. During this period the provisional restoration has to withstand the effects of the oral environment such as temperature variations which can range from $0^{o}C$ to $70^{o}C$; variations in acidity and alkalinity which can vary from a pH of 2 to around a pH of about 11; and high stresses which can be as high as several kilograms on one square millimetre of restorative material (Phillips, 1982; Craig, 1985 and McCabe, 1985). The selection of a particular provisional restorative material should be an important aspect of crown and fixed partial denture therapy.

The selection process should be based on an analysis of the situation which would take into consideration the requirements of that particular case and the properties of the materials available.

The requirements are variable and must be assessed for each case. In some cases the aesthetics, especially the colour, may be more important than the strength of the provisional restoration whereas in other cases the strength is of utmost importance. Cases which are provisionally restored on a long term basis to assess the occlusal or periodontal response to a particular modality of treatment are examples which require maximum strength of the material.

The properties of the available materials include the mechanical properties (strength), physical properties (colour), thermal properties (thermal conductivity), chemical properties (solubility) and biological properties (toxicity).

A comparison of the requirements and the properties of the materials available should enable the clinician to make the best choice for any particular case. The clinicians clinical experience of the material chosen will enrich his store of knowledge of the available materials and will also influence his future choice in a similar situation.

This selection procedure is diagrammatically illustrated in figure 1, which is adapted from McCabe (1985).
This present study will hopefully increase the knowledge of the properties available and influence the flow chart as shown in figure 1.

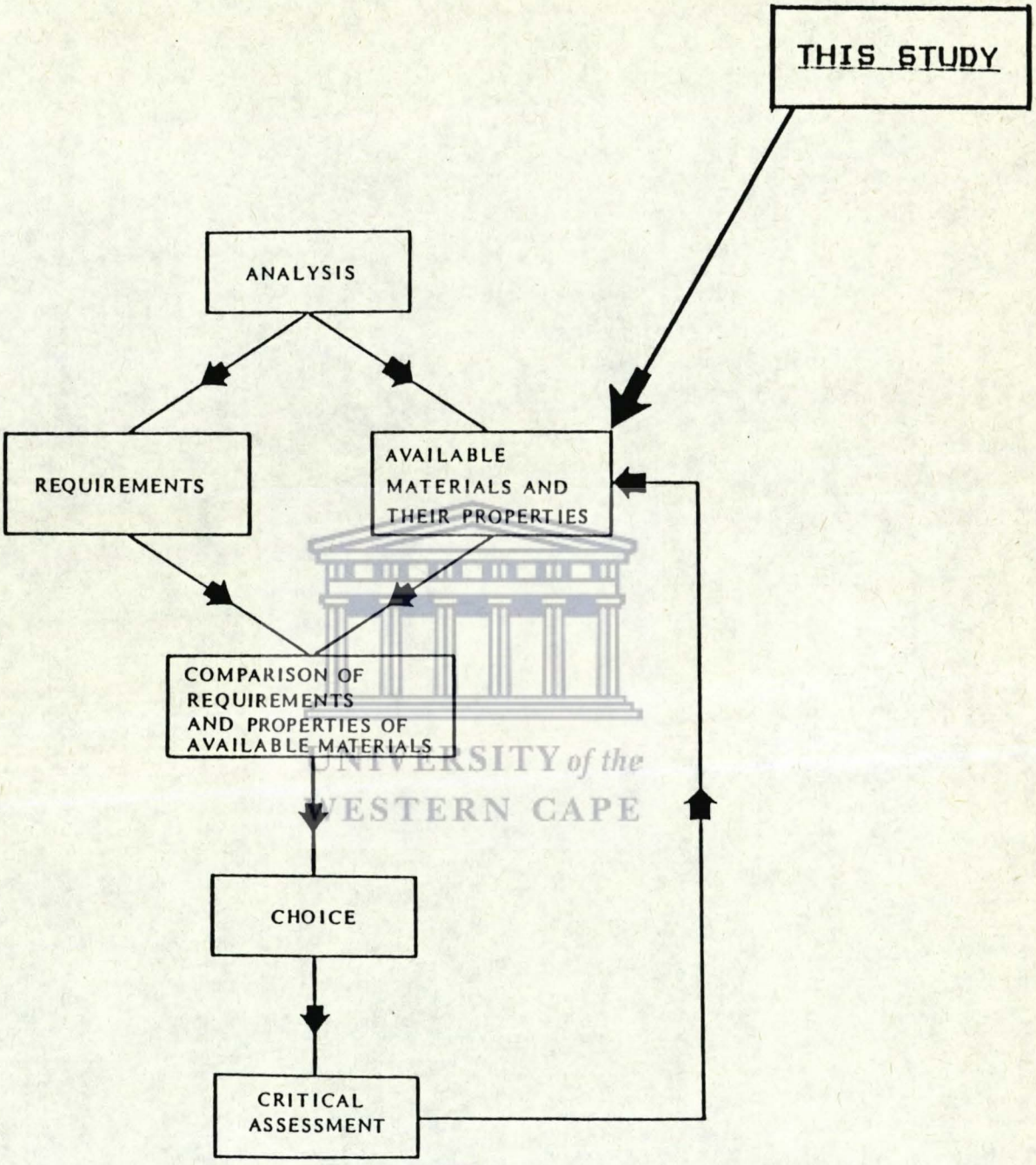


Figure 1 Flow chart indicating a method of material selection and the possible influence of the present study. Adapted from McCabe (1985)

CHAPTER 2 : CHEMISTRY OF THE PROVISIONAL RESTORATIVE MATERIAL

2. CHEMISTRY OF THE PROVISIONAL RESTORATIVE MATERIALS

2.1 The Methylmethacrylate or acrylic group. After Craig (1985) and McCabe (1985).

This is dispensed as a powder and liquid. The powder is a combination of polymethylmethacrylate beads and peroxide and the liquid is a combination of methylmethacrylate monomer and an activator. A pigment is added to match the natural tooth shades. This pigment is white, yellow or brown. The conversion of monomer molecules into polymers may proceed by either an addition reaction or a condensation reaction.
In this group of materials the setting reaction is by addition polymerization, which involves the joining together of two molecules to form a third, larger molecule. The reaction involves the addition of a reactive species with monomer to form a larger reactive species which is capable of further addition with monomer. The reaction may be visualized as:

$$R^* + M \longrightarrow R - M^*$$

$$R - M^* + M \longrightarrow R - M - M^*$$

$$R - M - M^* + M \longrightarrow R - M - M - M^*$$

The initial reactive species is represented by R*, the subsequent reactive species by -M* and the monomer molecules by M. The monomer molecules are added during each stage of the polymerization reaction and eventually a long chain molecule is produced.

The reactive species which is involved in the addition reaction may be ionic or it may be a free radical. The methacrylates as a group undergo a free radical addition polymerization reaction. The free radicals are produced by reactive agents called initiators, which are molecules containing one relatively weak bond able to undergo decomposition to form two reactive species, each carrying an unpaired electron. An initiator commonly used is benzoyl peroxide which is able to split to form two identical radicals. The decomposition of benzoyl peroxide is accomplished either by heating or by reaction with a chemical activator. The use of a chemical activator allows polymerization to occur at low temperatures. Activators used with peroxide initiators are aromatic tertiary amines such as N,N' dimethyl-p-toluidine.

The Polymerization process follows a well documented pattern which consists of four main stages:

(a) Activation

This involves the decomposition of the peroxide initiator by the chemical activator N,N' dimethyl-p-toluidine. For benzoyl peroxide the activation reaction is represented by the equation in figure 2.

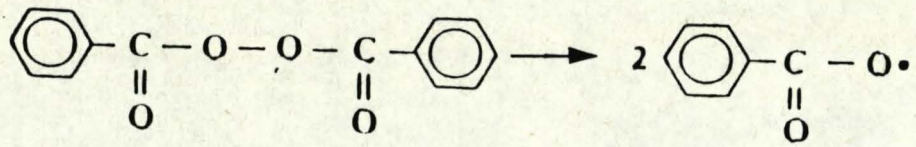


Figure 2 - Benzoyl peroxide readily splits to form two identical free radicals which can initiate polymerization.

This equation can be expressed in general terms as:

$$R - O - O - R \longrightarrow 2\ RO^*$$

Where RO* represents the radical group.

(b) Initiation

The polymerization reaction is initiated when the radical formed on activation reacts with a monomer molecule. This is illustrated by the equation in figure 3.

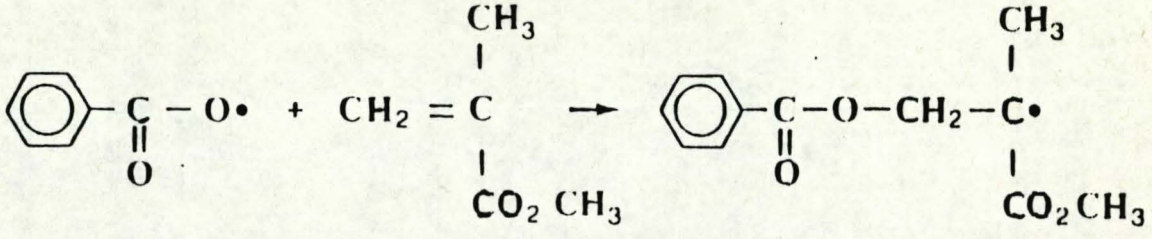


Fig. 3 - The reaction of a benzoyl peroxide radical with methylmethacrylate monomer to form a new radical species.

This reaction can be expressed in general terms as:

$$RO^* + M \longrightarrow RO = M^*$$

Where RO* represents the radical species and M the monomer which on combining produces another active free radical species (RO-M*) which is capable of further reaction.

(c) Propagation

The new free radical is capable of reacting with further monomer molecules. Each stage of the reaction produces a new reactive species capable of further reaction as illustrated below:

$$RO - M^* + M \longrightarrow RO - M - M^*$$

$$RO - M - M^* + M \longrightarrow RO - M - M - M^*$$

$$RO - M - M - M^* + M \longrightarrow RO - M - M - M - M^*$$

(d) Termination

It is possible for the propagation reaction to continue until the supply of monomer is exhausted. In practice however, other reactions, which may result in the termination of a polymer chain,compete with the propagation reaction. These reactions produce "dead" polymer chains

which are not capable of further additions. The combination of two growing chains to form one "dead" chain is an example of a termination reaction. Other examples of termination involve the reactions of growing chains with molecules of initiator, "dead" polymer, impurity or solvent if present.

2.2 The higher methacrylates

These are dispensed as a powder and liquid. The powder is a combination of polyethylmethacrylate beads and benzoyl peroxide with some pigments to match tooth shades, and the liquid is a combination of isobutylmethacrylate and an activator such as a tertiary amine.

Due to the presence of the higher methacrylates (ethyl and butyl-methacrylate) these materials have an increased dimensional instability when compared to the methylmethacrylates (McCabe 1985).

The setting reaction is also an addition polymerization reaction and follows the same stages as the methylmethacrylates .

2.3 The Epimine based resins

These are dispensed as a paste and a liquid. The paste contains an imine-terminated prepolymer and a polyamide filler. The liquid contains a sulphonic acid ester which is the reaction initiator. When the paste and liquid are mixed a cationic, ring opening addition polymerization reaction occurs. The ionized form of the sulphonic acid ester provides the initial source of cations and each stage of the reaction involves the opening of an epimine ring and the production of a fresh cation. Distinct activation, initiation and propagation stages may be identified in the reaction. The reaction is of the addition type with no by-products being produced. Each prepolymer molecule has two reactive epimine groups and this allows individual propagation reactions to produce either chain lengthening or cross-linking. As the reaction proceeds, the viscosity increases and eventually a relatively rigid cross-linked provisional restoration is produced.

2.4 The Composite Group (after Phillips 1982)

The composites as a group consist of an organic binder containing at least 60 per cent inorganic filler by weight. The filler particles are coated with a "coupling" agent to bond them to the resin matrix. The resin matrix is based at

least partially on Bowen's BIS-GMA resin which is synthesized by the reaction between bisphenol-A and glycidyl methacrylate. The coupling agent ensures a stable, adhesive bond of the filler to the resin thereby giving strength and durability to the restoration. The coupling agent usually has a silane-based component.

The composites used for provisional restorations are dispensed as a three paste system. The base paste contains the multifunctional methacrylic acid ester monomer and the filler. The two other pastes are catalyst pastes the one containing an initiator and the other containing an activator.

CHAPTER 3 : REVIEW OF THE LITERATURE OF PROVISIONAL RESTORATIVE MATERIALS

Contents

3.1 Introduction.

A provisional restoration should be treated for all intents and purposes as a permanent one, so that sufficient attention should be given to details such as marginal adaptation, embrasures and contact points. This will ensure optimal health of the abutments and the associated periodontal structures during treatment. Federick (1975a) stated that the provisional restoration should rather be called a "treatment" restoration.

Dwork (1981) stressed that the time spent on making a provisional restoration was well worth it, when it came to the final product. Good provisional restorations built rapport and helped to make the patients more receptive and expectant of the final product. He also found that these provisional restorations helped the healing process in the periodontal tissues thus minimising the discomfort at the final visit.

Krug (1975) found that the removal of tooth structure during crown preparation resulted in varying degrees of pulpal hyperaemia. The response of the pulpal tissues (recovery or degeneration) depended in part on the adequacy of the provisional restoration. Similarly the response of the gingival tissues depended to a large extent on the marginal adaptation of the provisional restorations.

3.2 Functions of the Provisional Restoration.

The functions of a provisional restoration can be grouped into four categories.

Tooth protection.

Maintenance of periodontal health.

Maintenance of intra- and inter-arch relationships and function.

Aesthetics.

3.3 Ideal properties of a Provisional Restoration. From McCabe (1985) and Vahidi (1985)

3.3.1. Setting Characteristics

a) It should have sufficient working time to allow mixing, placement and seating into the mouth.

b) After seating in the mouth, rapid attainment of a "rubbery" stage which would facilitate its easy removal without distortion.

c) Rapid hardening outside the mouth enabling trimming, polishing and cementation of the provisional restoration after a short time.

3.3.2. Biocompatibility.

It should ideally be non-injurious to the oral tissues since it comes into direct contact with freshly cut dentine and the oral mucosa.

3.3.3. Appearance.

Ideally it should be tooth coloured.

3.3.4. Mechanical Properties.

It should be strong and tough enough to resist fracture and wear in function and in parafunction.

Krug (1975) found from his work that the strength of the provisional restoration was the most important property. It was involved in one or another way in each of the major functions listed.

Russell (1986) defined, classified and examined the role of the provisional restoration in treatment planning. He singled out the strength of the provisional restoration as one of the most important factors, especially if the restoration was required for extended use in various situations.

3.4. Biological Response to the various Provisional Restorative Materials.

Before any material is accepted for clinical use its biocompatibility has to be proven. Dahl and Ostavik (1976) tried to determine the cytotoxicity of provisional crown and bridge materials using a cell culture system. They tested an epimine based material and a methyl methacrylate based material, and used zinc-oxide eugenol as the control. All

the materials tested were found to be cytotoxic in this particular cell culture system, zinc-oxide eugenol being most strongly so. Yet clinical experience and previous findings, have established that zinc-oxide eugenol is biologically well tolerated by the dental tissues. The authors concluded that all these materials would be clinically acceptable but since the results differed so markedly from the clinical situation for the control, these tests were not adequate screening tests for the biological compatibility of dental materials.

Tobias (1980) studied the histological effects of a temporary crown and bridge material (Scutan) on the pulps of canine teeth of ferrets at intervals of up to six months. After 24 hours a moderate to severe pulpal response was observed which persisted for up to six months. The inflammatory response was greatest beneath bacterially contaminated cavities. It seems fair to conclude that the bacteria played a more significant role in the pulpal inflammation than did the material as such.

Fleisch et al (1984) studied the pulpal response to another temporary crown and bridge material (Protemp) with and without a zinc-oxide eugenol liner in Vervet monkey incisor teeth. This study showed the low irritancy of Protemp which became even lower when a zinc-oxide eugenol liner was used.

The issue of pulpal response to provisional crown and bridge materials is still unresolved. There are various factors other than the material which influence the pulpal response.

These factors include bacterial contamination, the depth of the remaining dentine, the amount of reparative dentine, the preoperative status of the pulp and the post-operative "temporization" of the preparation.

3.5. The Marginal Adaptation of the Provisional Restoration.

The best possible marginal adaptation is essential to prevent the accumulation of plaque in the marginal defect between the restoration and the preparation. Good marginal adaptation is also essential for good aesthetics and to ensure minimal if any post-operative dentinal sensitivity.

Barghi and Simmons (1976) investigated methods which they felt would improve the marginal fit of provisional restorations. Their conclusion was that the acrylic resin provisional crown did not demonstrate well adapted margins prior to relining procedures. Venting of the provisional crown facilitated relining and improved the marginal adaptation significantly. A second venting and relining improved its adaptation but only slightly. From this study it became evident that all acrylic resin provisional crowns had to be vented and relined at least once to ensure optimal marginal adaptation.

Crispin, Watson and Caputo (1980) evaluated the marginal accuracy of nine provisional restorative materials using direct and indirect techniques. Their results showed that

the marginal accuracy of the provisional restorations made by the indirect technique as a group were significantly better than those made by the direct techniques. Their results also showed that when using the direct technique Snap had the smallest average marginal discrepancy. Although not a part of their study, it was noted that the methylmethacrylate materials (Duralay, Jet, Caulk's Temporary Bridge Resin) would polymerise on the surface before the rest of the material. As a result wrinkles formed while the material was being seated on the die, leaving an uneven surface and small marginal voids. This did not occur with any of the other materials tested.

Hunter (1983) described a modification of the resin template technique of making provisional restorations to improve marginal adaptation . He found that when resin was syringed into the gingival crevices and half way up the preparation prior to seating the template containing the rest of the resin, the marginal adaptation of the provisional restorations was significantly improved. However his study was purely anecdotal.

Monday and Blais (1985) designed a study to make quantitative measurements of the marginal space between the provisional restoration and the preparation. Their conclusions were twofold:

a) the indirect technique of making a provisional restoration produced less of a marginal defect than the direct technique. This was in accordance with the results obtained by Crispin, et al (1980).

b) the more subgingival the margins of the preparation the greater the marginal defect recorded between the provisional restoration and the preparation.

3.6. Techniques used in the production of the Provisional Restoration.

Adams (1970) described a technique for constructing a temporary fixed partial denture to replace a missing anterior tooth by attaching an acrylic resin denture tooth to the two abutment provisional crowns with self-cure acrylic. This technique is not very useful once two or more teeth have to be replaced.

Jordan et al (1980) developed a clinical technique for the fabrication of provisional fixed prostheses for missing single and multiple anterior teeth, using the acid-etch technique. This technique involved the use of acrylic resin teeth acid-etched to the abutments. Class III lingual approach cavity preparations were made in the proximal surfaces of the acrylic resin (pontic) teeth. The preparations were made self-retentive by the placement of undercut grooves in the axio-gingival and axio-incisal line angles. The abutments were cleaned with pumice and acid-etched for one minute with 30% phosphoric acid. A Bis-GMA bonding resin was then applied to the abutments as

well as into the preparations in the pontics. The composite material was syringed into the preparations and adapted to the abutments. After five to ten minutes of polymerization the excess luting resin was removed with the use of standard composite finishing instuments. Jordan and his co-workers found that if the instructions mentioned above were adhered to, the results obtained using this as a provisional restoration were exceptional. They reported on 86 cases and formulated certain guidelines for the success of such prostheses.

a) In cases of single or multiple incisor prostheses where the longevity required of the restoration was between three and nine months, the acid-etch resin alone would be adequate to retain the prostheses.

b) In cases where the longevity required of the prostheses was from a year to three or more years, accessory stabilization of the prostheses by means of pins was highly recommended.

c) In all cases optimal control of occlusal factors and co-operation of the patient would be essential prerequisites for the stability of the prosthesis.

La Vecchia et al (1980), like Adams (1970), used an acrylic resin denture tooth with composite resin to make a transitional anterior fixed prosthesis. In addition they used edgewise orthodontic wire to strengthen the provisional restoration. Two class III cavities with lingual locks were

prepared in the proximal surfaces of the abutment teeth. The lingual locks were of sufficient depth and width to accommodate a piece of 0.027 X 0.016 inch edgewise orthodontic wire and composite resin. A lingual channel was prepared in the resin pontic in line with the two class III preparations, using a number 35 inverted cone bur. One end of the wire was sealed into one of the cavities with composite resin and then into the other end. The pontic was then aligned such that the wire would lie passively in the lingual channel before the channel was filled with composite resin. According to the authors the longevity of this provisional restoration was largely dependent on how well the pontic could be taken out of the occlusion.

Ferencz (1981) utilized a "shell" technique. Thin acrylic shells were constructed inside an alginate impression of the unprepared teeth, or from the restored diagnostic models. These shells were fabricated by dropping acrylic monomer into the alginate impression to fully wet the area of the teeth to be restored. The polymer was sprayed into the impression to completely absorb all the liquid. This was repeated four or five times until the desired thickness of 1/2 to 1 mm of the shell was built up. Once the acrylic had set it could be gently teased out of the alginate impression, ready to be relined with the appropriate shade of acrylic at the completion of the preparations. He found this technique most useful especially when the provisional restoration had to fuction for extended periods of time while adjunctive therapy was being performed.

Dwork (1981) described a technique using a vacuum moulded coping matrix and a self-cure resin, Snap. This coping matrix was made using a diagnostically waxed-up model. The placement of the resin into this coping matrix and then onto the preparations would result in an exact positioning of the provisional restoration as regards function and aesthetics. The coping matrix could be removed as soon as the resin had polymerized, enabling trimming and cementation of the provisional restoration.

Miller (1983) described a technique whereby polycarbonate crowns and self-cure acrylic resin are used to provide fixed provisional restorations for short span bridges. The polycarbonate crown was used because of its aesthetics, axial contours, occlusal edge design, occlusal table design and its convenience in kit form. In this technique an auto-polymerizing acrylic resin wash was used in the appropriate polycarbonate crown for the abutments. A length of beading wax was placed along the edentulous ridge in apposition with the lingual aspect of the abutments but clear of the opposing arch in centric occlusion. Polycarbonate crowns were then adapted to the wax. Once satisfied with the appearance, auto-polymerizing acrylic resin on a camel-hair brush was used to cement the individual pontics and abutments at the contact areas directly in the mouth. After the material had set the splinted units were removed from the mouth, the polycarbonate pontics filled with auto-polymerizing resin and allowed to polymerize outside the mouth. The provisional restoration was then trimmed and cemented in the

usual manner ensuring clearance between the pontics and the tissues of the ridge. The author did not give scientific evidence but stated that from his clinical experience he has found these restorations to be strong and capable of extended use when frabricated in a dry field. He had monitored some of these provisional restorations for a year in patients undergoing periodontal therapy, without any signs of joint fracture.

Daly and Wilkinson (1983) described a technique whereby a patient's natural crown was used as a pontic. The major advantage of using this technique was that it provided the optimal pontic in terms of shape, colour, size and alignment. However this technique could only be used in certain parts of the mouth where the strength of the provisional fixed partial denture was not of utmost importance. The authors described a case where the lower left central incisor was periodontally involved and had to be extracted. The involved tooth and the two adjoining teeth were thoroughly cleansed, isolated with cotton rolls and etched with 37% phosphoric acid for one minute. After washing and drying them, the left central was bonded to the adjoining teeth using visible-light cured, micro-filled resin. Once the resin had polymerized the pulp chamber of the left central was entered from the lingual surface for debridement. Amalgam was then packed into the chamber and into the canal, past the projected point of root resection. When the amalgam had set the root was separated from the crown with a diamond bur and removed. The cut surface was rounded and smoothed to ensure minimal plaque retention.

The case described by Daly and Wilkinson was of a provisional fixed partial denture which had been in place in the lower anterior region for the past 17 months.

La Barre (1983) described a technique for fabricating separate adjacent provisional restorations from a single mix of autopolymerizing acrylic resin. This was also a modification of the template technique. The template was sectioned with a saw while it was positioned on the diagnostic model. Mylar strips were then placed in the saw-cuts. The template together with the mylar strips in position was filled with auto-polymerizing resin and placed over the preparations resulting in adjacent but separate provisional restorations.

Kinsel (1986) modified the "shell" technique by incorporating acrylic resin denture teeth facings into the shell. This was done mainly for aesthetics. To improve on the strength of the provisional restoration he placed a thread mate system (TMS) regular pin into the interproximal surfaces of the pontics and abutments.

3.7 Review of tests comparing the strength of various provisional restorative materials.

The strength of a material has always been one of the important criteria for the selection of that particular material. Peterson, Phillips, and Swartz (1966) studied four commercially available auto-polymerising restorative resins which were thought to be representative of those

being marketed at that time. They were all based on the methyl methacrylates. The resins were compared on the basis of various qualities, and the study revealed that no one resin was superior to another as regards strength. There was no real difference in the hardness of a given material at day one as compared with the hardness at one week. This study paved the way for future comparative studies.

Braden, Causton, and Clark (1971) investigated an ethylene imine derivative as a temporary crown and bridge material and found that the setting reaction was only slightly exothermic when compared to the methylmethacrylates, and was therefore kinder to the pulp. They also found that there was no free monomer during the setting process which was also biologically more acceptable than with the methylmethacrylates. Their results showed that this ethyline imine derivative was mechanically weaker than the methylmethacrylates at that time (1971).

From a review of resins available in 1975 Krug (1975) found that there were only three types available for the construction of custom provisional restorations. These were the:

(a) Methylmethacrylates, which had long been on the market (since 1940). The polymerization of this resin resulted in an exothermic reaction which could be detrimental to the pulp. Also the monomer had a very pungent odour and could cause a sensitivity reaction in the periodontal tissues.

(b) Polyethylmethacrylates which were supposed to have been an improvement on the methylmethacrylates. They succeeded in reducing the exothermic irritation to the pulp and also reducing the effects of the monomer, but seemed to have been less successful as far as hardness and strength were concerned.

(c) The epimine-plastic (Scutan) which was an epoxy resin where the oxide group was replaced by an imino group. It contained no monomer and this was a definite advantage. The disadvantages listed by Krug (1975) included cost, lack of fluidity when poured and a limited selection of shades. They were also mechanically weaker than the methylmethacrylates.

In 1976, when Braden et al investigated a new provisional restoration material (Crobrit) which had just come on the market, it was found that the epimine based material (Scutan) had improved substantially in its mechanical properties since the last test in 1971, but was still inferior to the other materials (the methylmethacrylates and the higher methacrylates) available at that stage.

A review by Vahidi (1985) listed a fourth type of material that is a biacrylic composite system. According to Vahidi this composite did not shrink, it could be added onto with both visible-light cured composite and with the traditional autopolymerizing acrylic. It could also be custom-stained with either composite or acrylic staining kits. The

disadvantages listed included the brittleness of the material in long span bridges and the relatively high cost. Up until then no comparative test for strength had been done using this new material.

Goldstein (1985) described three clinical cases where visible light activated composite resin systems were used as an adjunct in the fabrication of fixed partial prostheses. The strength of the composites in all the cases was more than adequate. The visible light activated composite system was also used to make a shade tab which was then characterized with composite colour matching which the technician could use when fabricating the permanent restoration.

Gregauff and Pryor (1986) described an experiment comparing the fracture toughness of four classes of resins used for provisional restorations. Their results showed that the epimine based resins and the two methyl methacrylates had the greatest fracture toughness. The poly (R' methacrylates) (where R represented any organic group other than methyl e.g. ethyl) had the lowest fracture toughness and the composites showed an intermediate value. Their experiment also showed that the use of a pressure vessel during polymerization did not significantly increase the fracture toughness of the six resins tested.

Table 1 summarises the literature on comparative strength studies.

Table 1: Summary of reviews comparing strength of various provisional restorative materials.

Author	Materials tested	Results
Petersen *et al* 1966	All methylmeth-acrylates	No difference in strength
Braden *et al* 1971	Methylmethacrylate Ethylmethacrylate Epimine based	Methyl- and Ethylmethacrylate had greater strength than the epimine based materials
Krug *et al* 1975	Methylmethacrylates Ethylmethacrylates Epimine based	Methylmeth-acrylates strongest
Braden *et al* 1976	Methylmethacrylate Ethylmethacrylate Epimine based	Improved strength of epimine but methyl and ethyl still stronger
Vahidi 1985	Methylmethacrylates Ethylmethacrylate Epimine based Composites	Methyl the strongest
Gregauff *et al* 1986	Methylmethacrylates Ethylmethacrylates Epimine based Composites	Epimine and Methyl the best, composites inter-mediate and ethyl the weakest

3.8 The importance of strength and means of improving the strength of provisional restorations.

Federick (1975) described a case where a patient had to wear a provisional restoration for almost a year while the periodontal condition was being assessed and treated. This was an example of where the strength of the provisional restoration was of vital importance to the eventual success or failure of the permanent restoration.

Kantorowicz (1978) discussed ways of filling the huge gap between the pontic and the mucosa in cleft palate patients treated with fixed partial dentures. He mentioned two alternatives - one was the use of an acrylic gum-piece which fitted like a precision attachment to the pontic. The disadvantage was that it could get lost and its replacement may have been very difficult, even impossible. The other alternative was the use of an extended pontic. This was done during the provisional or treatment restoration phase when the pontics were extended towards the mucosa with auto-polymerizing acrylic to form "roots". The form of these "roots" was developed by trial and error, once again stressing the importance of the strength of the provisional restoration during that experimental period.

Doherty (1979) described a technique for making a strong provisional restoration using a celluloid matrix with metal bands. The bands could be of gold, copper or aluminium.

He listed the advantages and the disadvantages of the various bands. Amongst the advantages was the greater strength of the provisional restoration and the better marginal fit (anecdotal).

Kastenbaum (1982) listed the requirements of an ideal provisional restoration which are in agreement with the ideal properties listed previously. He also listed the advantages of a heat-cured acrylic as a provisional restoration when compared to the auto-polymerizing provisional restorations. From his clinical experience and case histories he found a greater strength in the heat-cured acrylic as compared to the self-cured and presumed this to be due to its denser and therefore less porous nature.

Davidoff (1982) recommended the incorporation of a non-precious metal casting into the acrylic resin during processing, to increase the strength. The metal casting was fabricated to transgress the pontics and was incorporated into the lingual and or occlusal surfaces of the abutments. However, Davidoff did not give scientific evidence to support this recommendation and it was probably based on his clinical experience.

Ruffino (1985) studied the effect of steel strengtheners on the fracture resistance of an acrylic resin complete denture base and found:-

(a) that the strengthener had to be placed perpendicular to the anticipated line of stress and fracture to be effective.

(b) all strengtheners caused a discontinuity in the material thus weakening it, but the thick steel strengtheners (1,1 X 2,5mm), perhaps because of their greater resistance to deflection, seemed to be more effective than the thin steel strengtheners (o,8 X 2,4mm).

3.9 CONCLUSIONS

The fabrication of a provisional restoration is an important phase in crown and fixed partial denture therapy. If sufficient care is not taken during this phase of the therapy, the final restoration may be compromised.

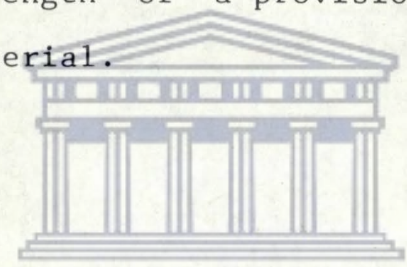
Davidoff (1982) found that the success of the provisional restoration was directly proportional to the amount of preparation and planning involved.

Miller (1983) found that the detrimental effects of an inadequately designed and hastily fabricated provisional restoration could be irreversible.

A review of the literature has shown that the materials being analysed in this study can all fulfil the functions of a provisional restoration. None of the materials possess all the properties of an ideal restorative material but they all possess enough properties to function adequately as provisional restorations. If enough care is taken in their manipulation they all seem to be biologically acceptable as provisional restorations. The marginal adaptation of all the

materials seems to be acceptable and there are ways and means of improving this marginal adaptation. There are various techniques which can be used in the production of the provisional restoration and these techniques can be used with any one of the materials being studied. However this review failed to show any one of the materials studied to be consistently superior as regards strength of the provisional restoration.

It also failed to show conclusively the effect, if any, of inserts on the strength of a provisional crown and fixed partial denture material.



The objectives of the study were:

1. To determine the relative strength of five provisional restorative materials from the four groups of auto-polymerizing materials using controlled experimental conditions.

2. To determine the differences if any in strength between the newer generation and the older generation methyl- methacrylates.

3. To determine the differences if any in strength between the strongest auto-polymerizing material and a heat-cured provisional crown and fixed partial denture material.

4. To investigate the ultra-structural surface of the fracture face of the specimens.

CHAPTER 4 : MATERIALS AND METHODS

4.1 MATERIALS.

Five materials were chosen representing the four major groups of auto-polymerizing provisional crown and fixed partial denture materials. Two materials, Caulks temporary crown and bridge resin and G.C. Unifast temporary resin were chosen as representative of the old and the new generation methylmethacrylates respectively.

Caulks Temporary Bridge resin is manufactured by the L.D. Caulk Company which is a division of Dentsply International Incorporation in Millford, Delaware, United States of America. The batch used for the experiment was 040378. G.C. Uni-fast is manufactured by the G.C. Dental Industrial Corporation in Japan. The batch used for the experiment was 090661.

Snap was selected as a representative of the higher methacrylates. It is manufactured by the Parkell Bio-Materials Division in Farmingdale, New York, United states of America. The batch used for the experiment was 85151.

Scutan was selected as a representative of the epimine based resins. It is an ESPE product and is manufactured by the ESPE Fabrik pharmazeutischer paraparate GMBH, in Seefield/Oberbay, West Germany. The batch used for the experiment was D017.

Protemp was selected as the representative of the Composite based resins. This is also an ESPE product and is also manufactured in Seefield/Oberbay, West Germany. The batch used was N112.

For completeness a heat cured material was also selected for the experiment. The material used was Biodent crown and bridge material manufactured by De Trey in West Germany. The heat-cured specimens were all prepared and cured in the laboratory under the same conditions for the manufacturing of a laboratory processed heat-cured temporary crown and bridge. The batch number of the material used was 0693.

4.2 METHOD.

A method had to be devised to make standard specimens of each material for the tests. A plaster mould was tried but the specimens were not consistently repeatable. Eventually a brass mould was designed on a split cast principle. Its operating mechanism is similar to that of a denture flask. It has a base with four prongs, one in each corner, a central part with two grooves which is designed to contain the material, and a cover which fits over the whole assembly (Figure 4). A pilot study revealed that all specimens manufactured using this mould were identical in size.

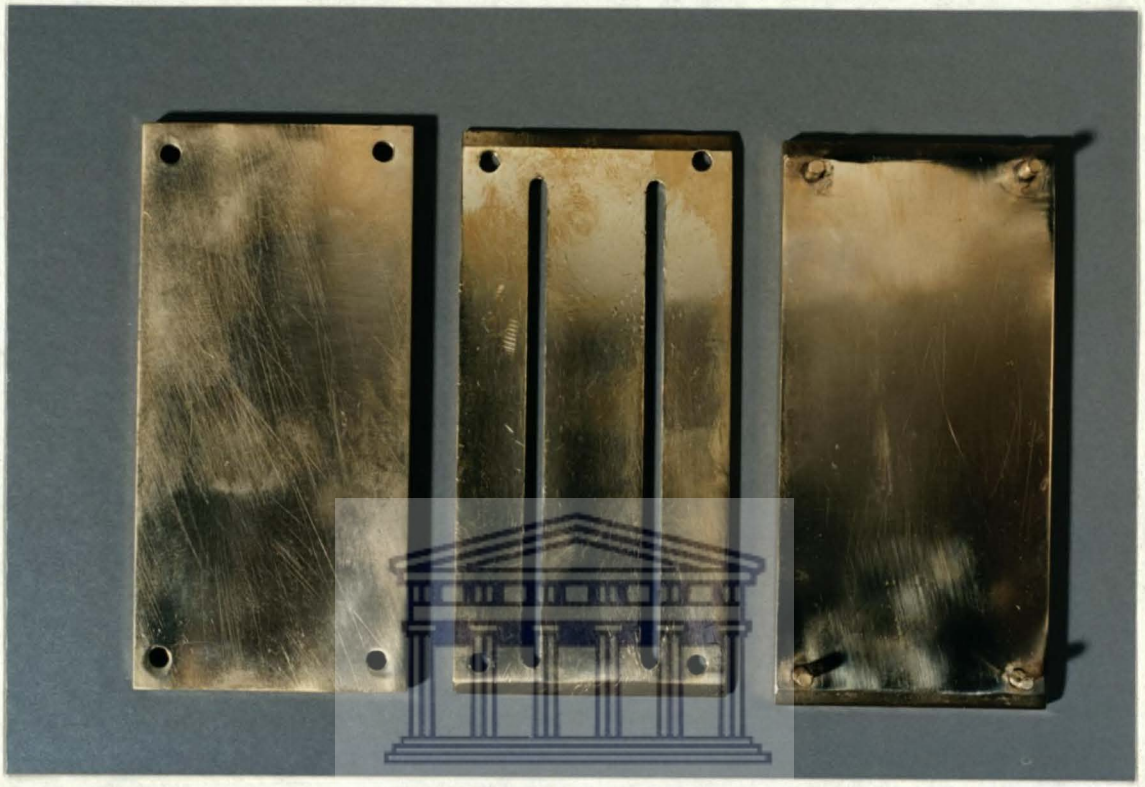


FIGURE 4 photograph of the mould used to manufacture the specimens for the tests.

One of the problems encountered in the fabrication of these specimens was the use of a separating medium. A silicone spray was tried but found wanting. Polythene sheets were tried but a reaction occurred between the sheets and some of the materials to be tested. Tin foil produced the best and most consistent results as a separating medium. Figure 5 shows the tin foil in position.

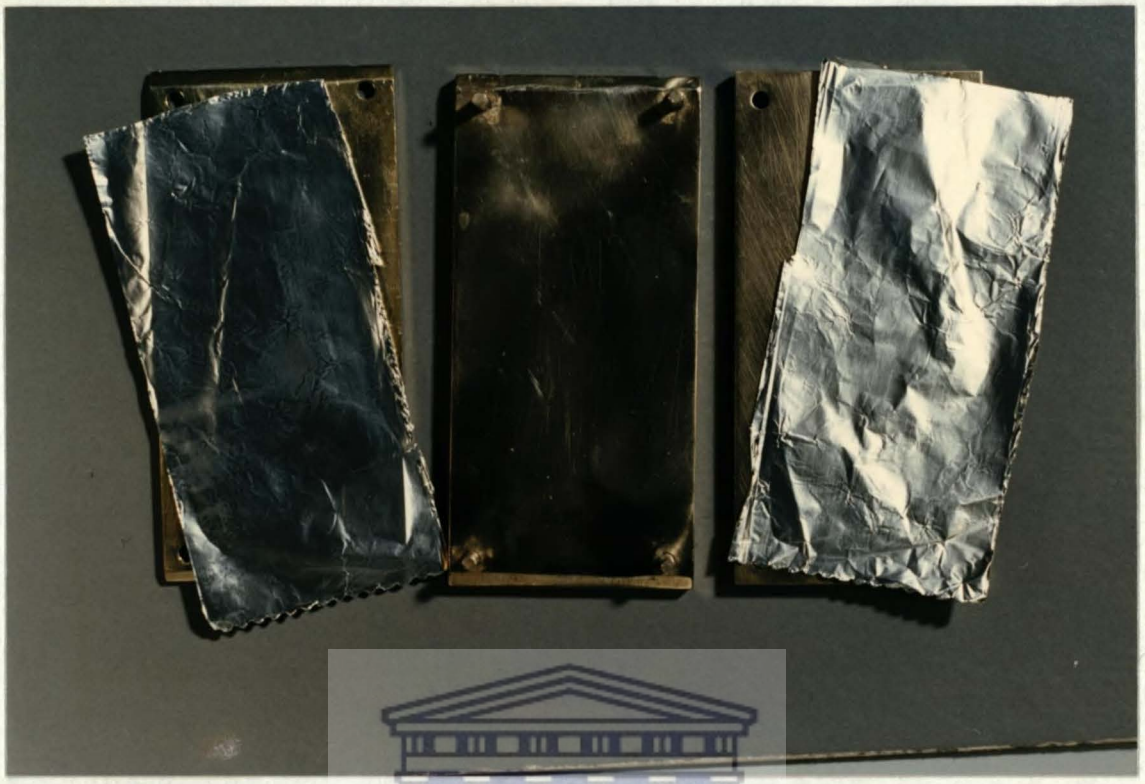


FIGURE 5 mould with tin foil as a separator in position.

The procedure for making the specimens was standardised. All the materials used during the experiment came from the same batch for each manufacturer. The materials were mixed using weighed quantities of powder and a predetermined volume of liquid pipetted into the powder. The materials were mixed according to the manufacturers' instructions under clinical conditions and syringed into the mould and allowed to bench cure for twenty minutes under a constant pressure of 500 grams (Figure 6).

FIGURE 6 mould under a constant pressure of 500 grams during polymerization of the material.

The specimens were all identical in size and measured 3 mmm by 5 mm by 90 mm (Figure 7).

FIGURE 7 specimens used for the destruct tests.

The specimens were all stored at room temperature for 24 hours and then incubated in normal saline at 37°C for at least twenty four hours. This was done to simulate the oral environment.

The specimens were then subjected to destruct tests on the Instron machine according to computer generated random numbers. The machine used was the J.J.Tensile testing machine type T5001 with a cross head speed of 5mm per minute. Figure 8 shows the position of the specimen in the Instron machine during the destruct tests.

FIGURE 8 Specimen in position in the Instron machine during the tests.

The operator performing the destruct tests did not know which numbers belonged to which material.

The Instron machine was calibrated to a load cell sensitivity of one with a paper cross-head ratio of 1:1. It had a load cell rating of five kilonewton (5KN). This meant that a pen movement of 250mm on the graph paper was representative of a force of five kilonewtons being applied to the specimen.

When the specimens were fractured the ends were observed under a laboratory magnifying glass. The presence of any air bubbles within the fracture face of the specimen excluded the specimen from the experiment.

SEM Study

After the work by Crispin et al (1980) where they looked at the fitting surfaces of provisional crowns and bridges and found wrinkles and voids in these surfaces when methylmethacrylates were used, it was decided to look at the fracture faces of at least one specimen from each group under a scanning electron microscope (SEM).

The specimens were prepared using an acrotome. These preparations were mounted on SEM Discs with the fractured face facing upwards. These discs were dried using liquid carbon dioxide in the drying machine. They were gold sputtered to enable SEM observations. During observation of the samples it was clear that the surfaces of each specimen

showed little variation. It was therefore decided to make only two photographs at 200 and 400 magnification. The photographs were examined to record the presence of voids and fracture planes.

Figure 9 shows a preparation mounted on a SEM disc, gold sputtered and ready for SEM observation.

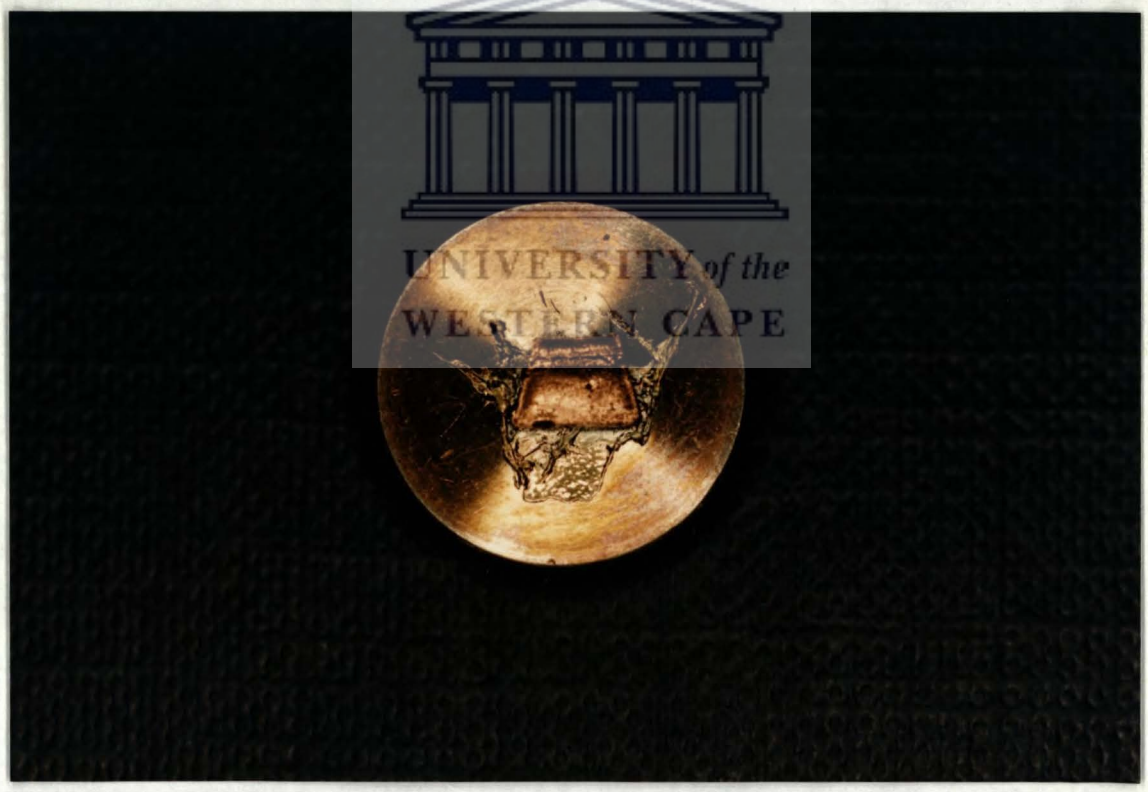


FIGURE 9 : Gold sputtered preparation prior to SEM observation.

Analysis of data

Using a code the specimens fractured were identified and the results were tabulated.

To test for a significant difference between the five groups of the autopolymerizing materials a one way analysis of variance (ANOVA) test was used.

To test for differences between two groups at a time the Mann-Whitney U test was used.

The results were represented using bar charts.

CHAPTER 5 : RESULTS

5.1 Results.

The results obtained were in millimetres and represented the distance the pen moved on the graph paper until the moment the specimen fractured.These results had to be converted to Kilonewtons required to fracture the specimen.

force of 5 KN represented a pen movement of 250mm

force of x KN represented a pen movement of ymm

5 KN = 250mm

$$x\ KN = \frac{ymm}{250mm} \times \frac{5\ KN}{1}$$

$$x\ KN = \frac{y}{250} \times 5\ KN$$

Where xKN was the force required to fracture the specimen and y mm the pen movement at the time of fracture of the specimen. The values for each specimen were tabulated (Table 2)

The flexural strength for SNAP ranged from a minimum of 0,132KN to a maximum of 0,568KN with a mean of 0,464KN and a standard deviation of 0,16KN. Of the eleven specimens tested 8 ranged from 0,528KN to 0,568KN with two specimens of 0,132KN and 0,148KN respectively and one specimen of 0,472KN.

The flexural strength for the methylmethacrylates ranged from 0,212KN to 0,267KN with a mean of 0,235KN and a standard deviation 0,015KN.

The flexural strength for the composite Protemp ranged from 0,125KN to 0,205KN with a mean of 0,171KN and a standard deviation of 0,03KN.

The flexural strength of the epimine based resin Scutan was the least of all the materials tested. It ranged from 0,118KN to 0,178KN with a mean flexural strength of 0,144KN and a standard deviation of 0,02KN.

The flexural strength of the heat-cured specimens was somewhere between that of Protemp and that of Scutan with a mean value of 0,16KN and a standard deviation of 0,01KN. The values for these specimens ranged from 0,14KN to 0,18KN.

5.2 Statistical Analysis

after Allan (1982) and Wastall (1987)

The results of an analysis of variance test (ANOVA) applied to the data, revealed an F value of 31,41 for the five groups of autopolymerizing materials at 4 and 50 degrees of freedom which gave a P value of less than 0,005 making the differences between the groups statistically significant (Table 3).

To test for significant differences, if any between any two materials at a time the Mann-Whitney U test or the median test was used, where for a U value equal to 30 p is equal to 0,05 for N1 = 11 and N2 = 11, that is, for a statistically significant difference between two materials at the 5% level the U value had to be less than 30 (Table 4).

From the data histograms were drawn for each material using the X-axis for the specimens tested and the Y-axis for the force in kilonewtons required to fracture the specimen. (Figures 10 - 15).

Using the mean and standard deviation for each material a composite histogram (figure 16) was constructed to compare the relative strength of each material, and a graph drawn (figure 17) comparing the strength of the older and the newer generation methylmethacrylates (represented by Caulks temporary bridge resin and G.C.'s Unifast temporary resin).

Figure 18 is a graph comparing the strongest of the autopolymerizing materials (Snap) with the heat cured material (Biodent).

Table 2.

Flexural Strength of Materials tested in Kilonewtons (KN)

Protemp	Scutan	Snap	Caulks	G.C.	Heat-Cured
0,13	0,13	0,47	0,23	0,27	0,16
0,20	0,12	0,54	0,23	0,24	0,16
0,19	0,15	0,53	0,23	0,25	0,18
0,15	0,14	0,54	0,25	0,25	0,18
0,20	0,17	0,13	0,23	0,22	0,14
0,19	0,17	0,56	0,24	0,23	0,15
0,21	0,14	0,55	0,23	0,24	0,16
0,18	0,18	0,57	0,21	0,23	0,14
0,15	0,17	0,53	0,23	0,22	0,14
0,15	0,12	0,15	0,26	0,22	0,14
0,16	0,12	0,54	0,25	0,23	0,16
Total 1,88	1,59	5,10	2,58	2,58	1,71
Mean 0,17	0,14	0,46	0,23	0,23	0,16
S.D. 0,03	0,02	0,16	0,01	0,02	0,01

rug: 0,54 mean
0,03 S.D. (0,0283)
variable B
Calculated = 5.62

Protemp

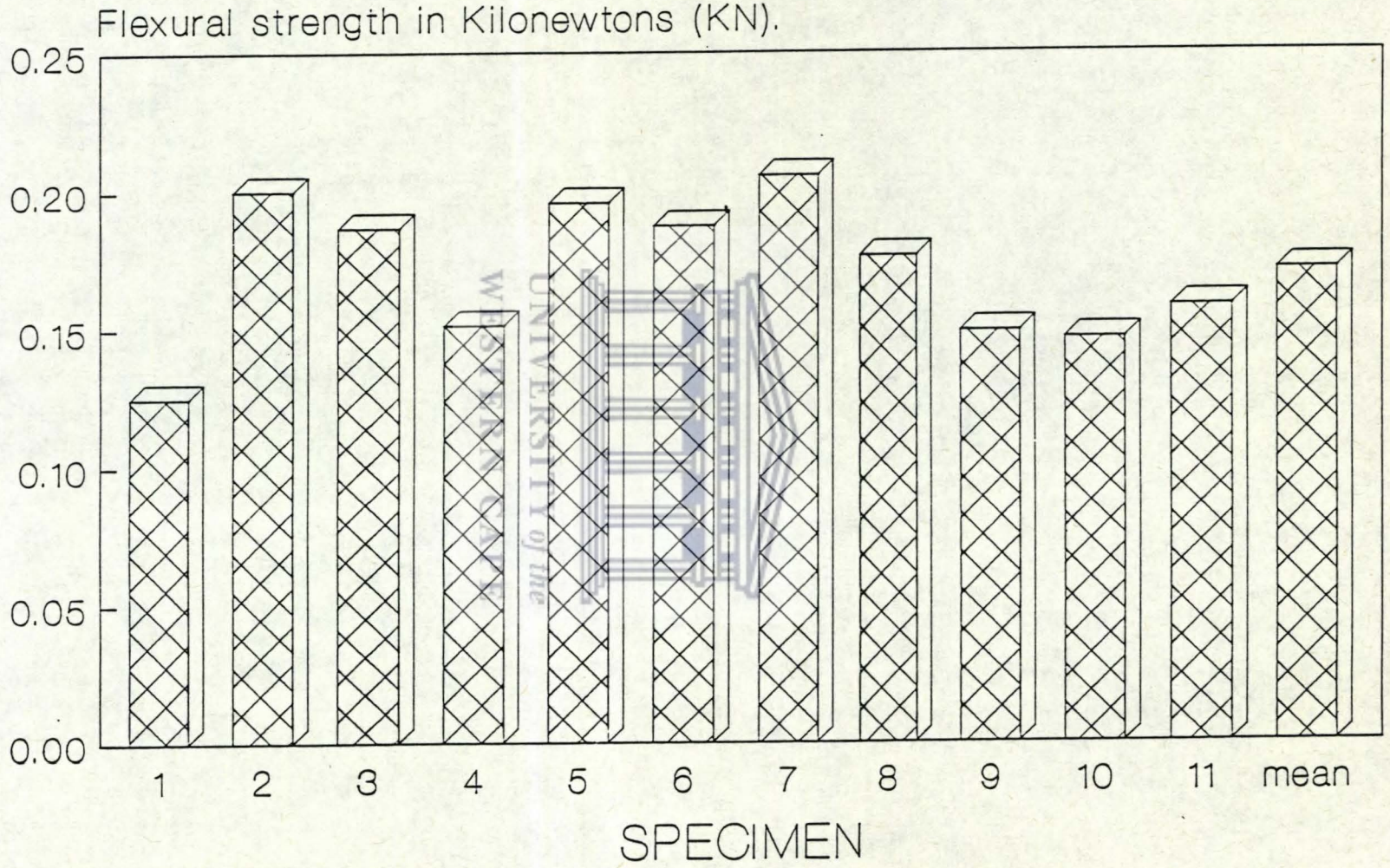


Figure 10 Values for Protemp specimens.

Scutan

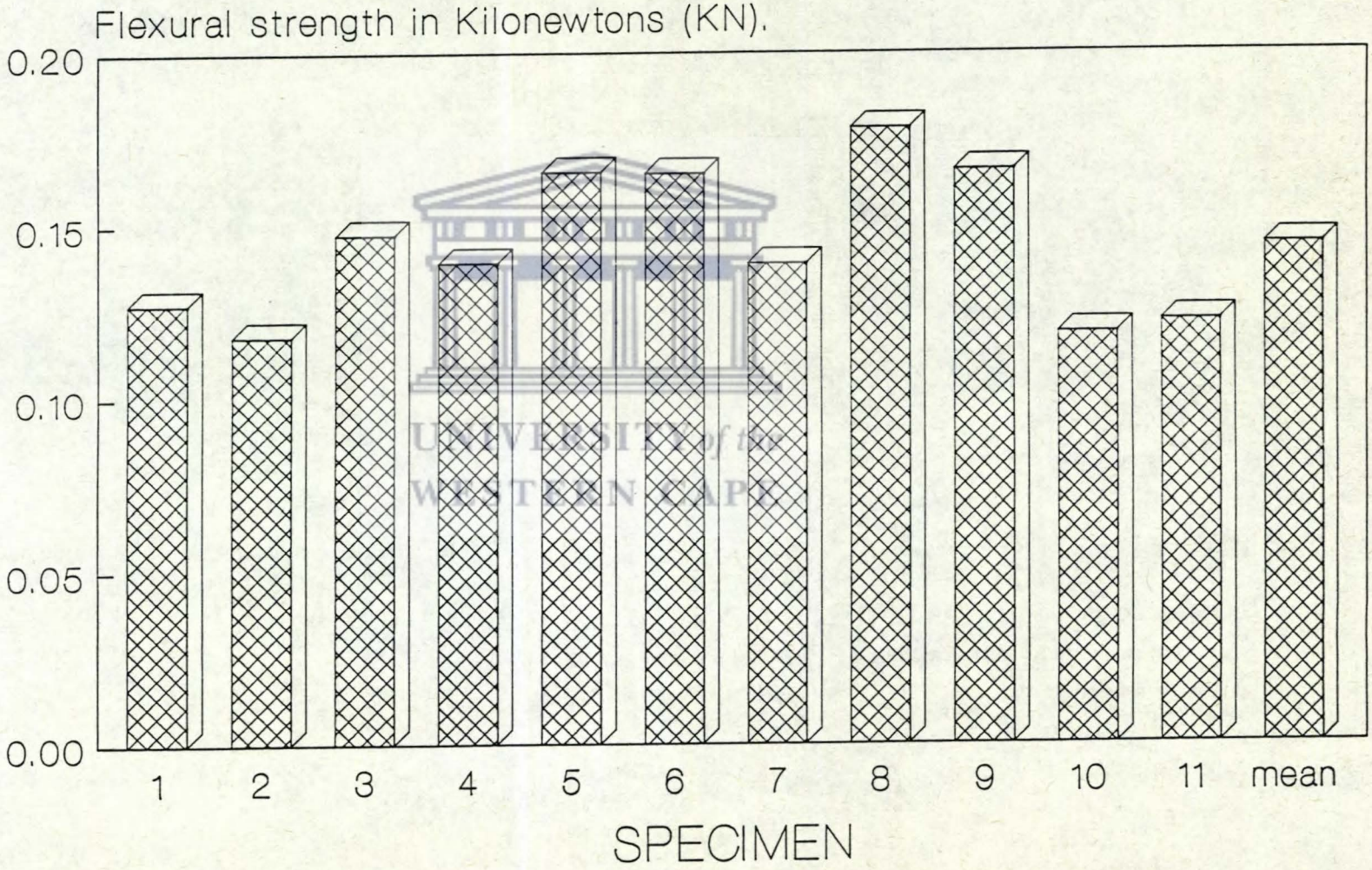


Figure 11 Values for Scutan specimens.

Snap

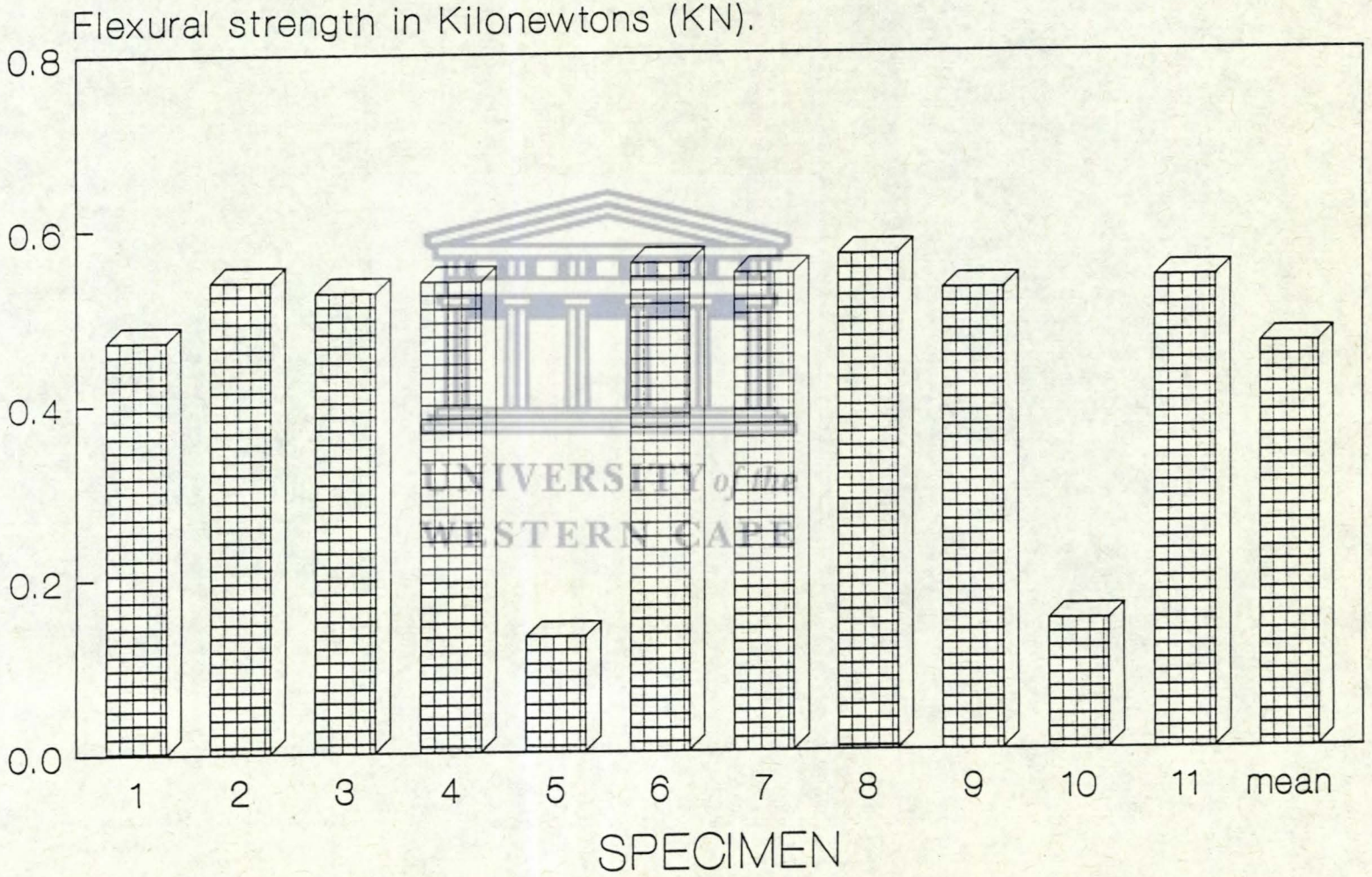


Figure 12 Values for Snap specimens.

Caulks

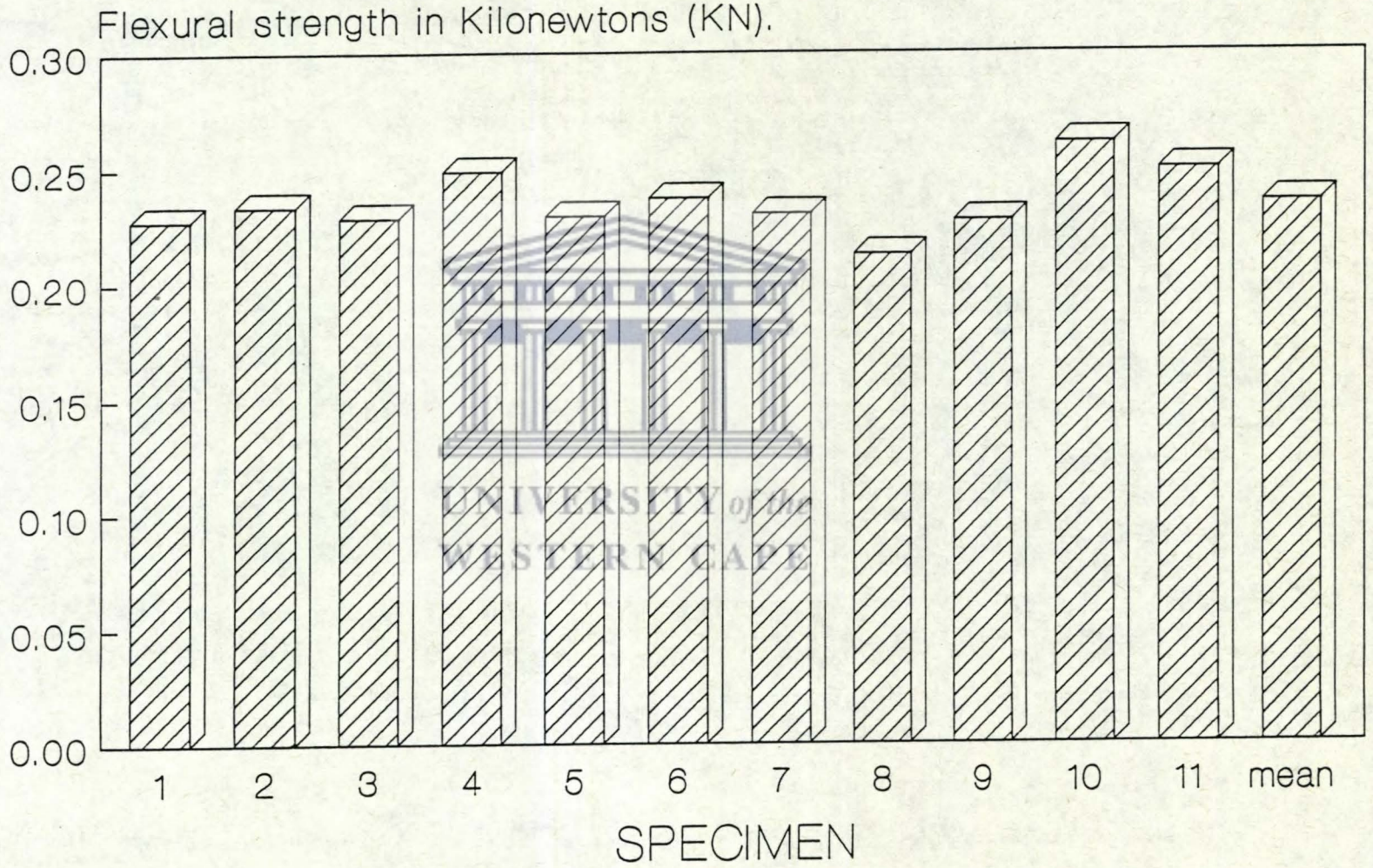


Figure 13 Values for Caulk specimens.

G.C.

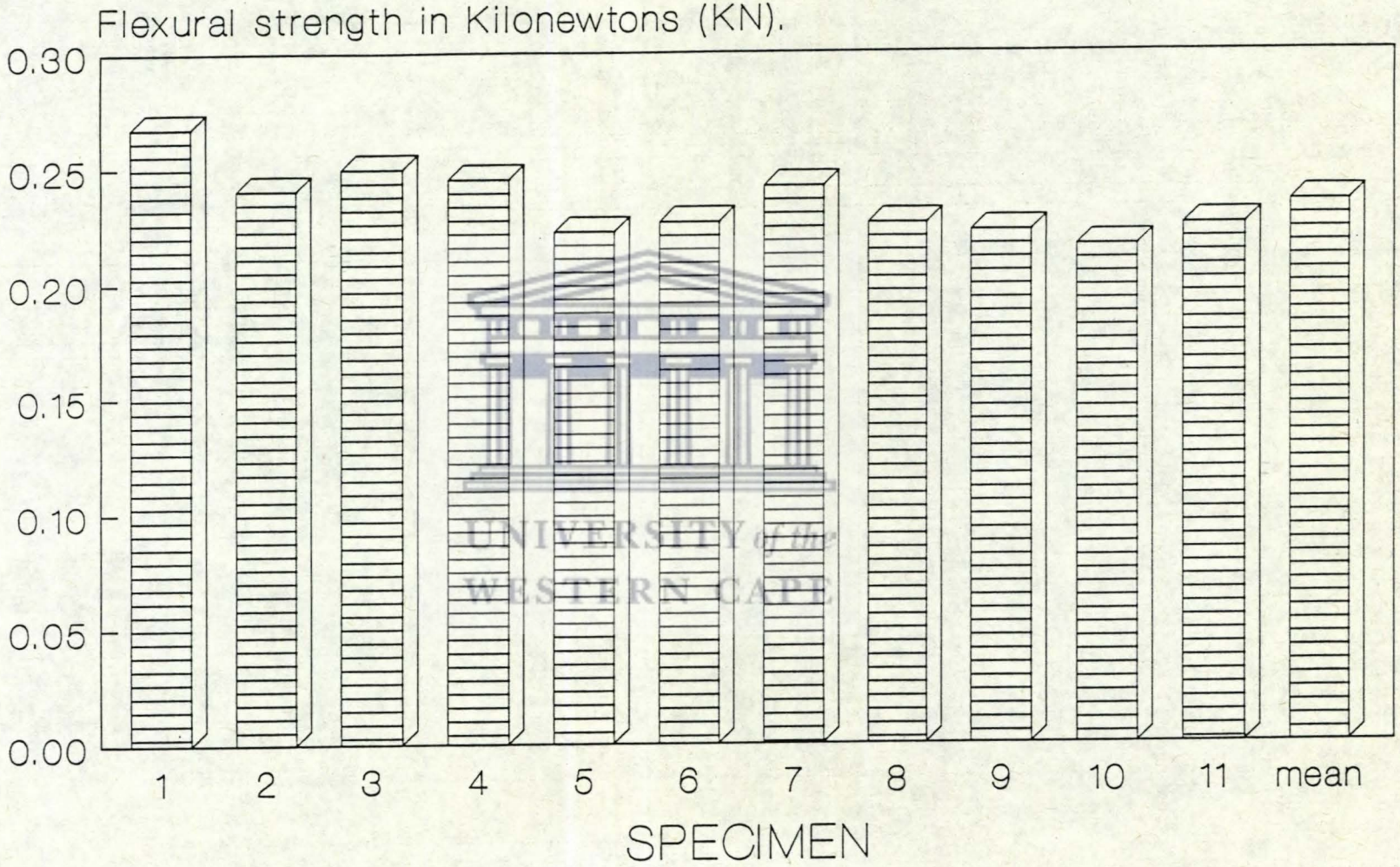


Figure 14 Values for G.C. specimens.

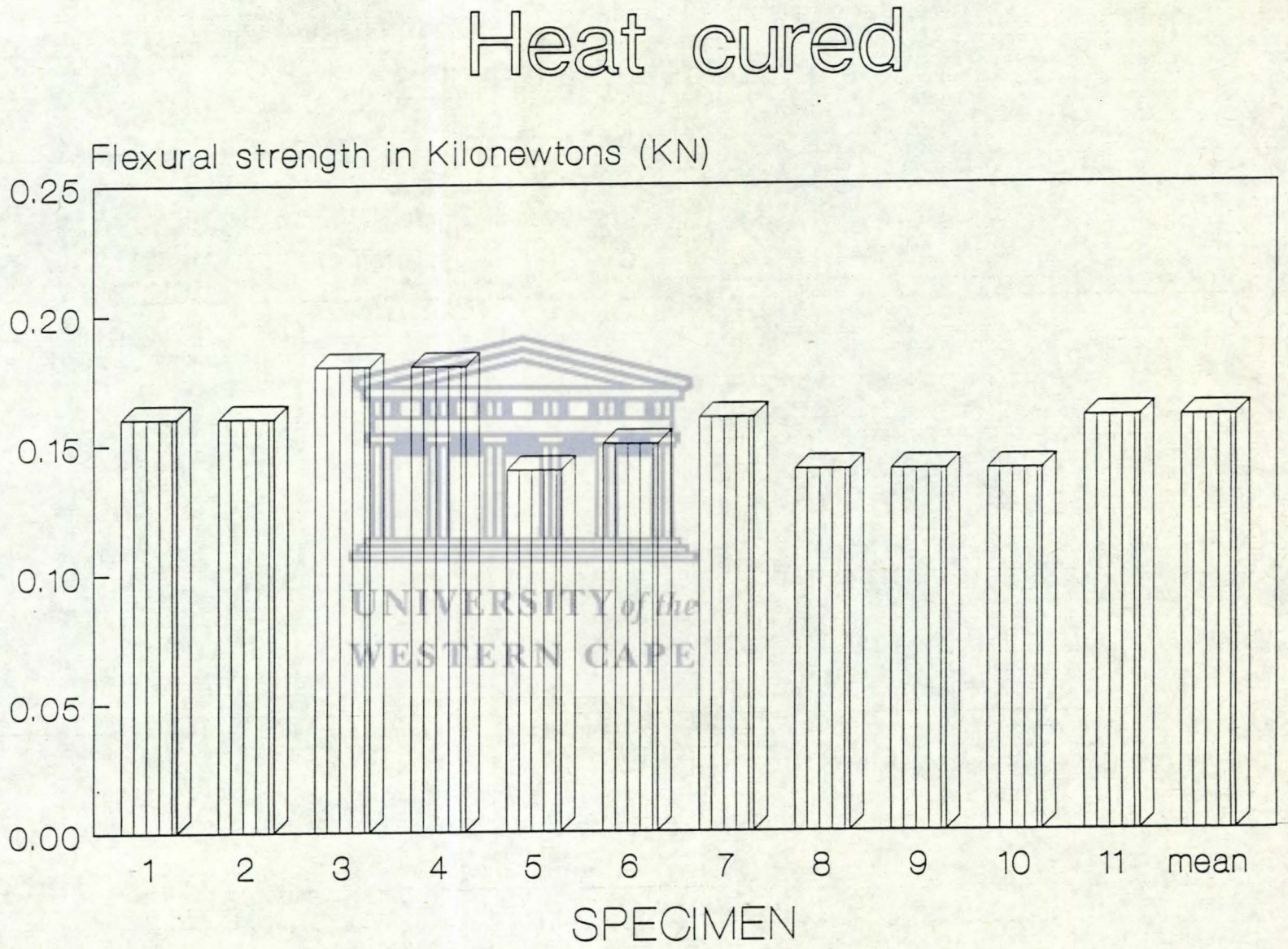


Figure 15 Values for Heat-cured specimes

Composite Histogram.

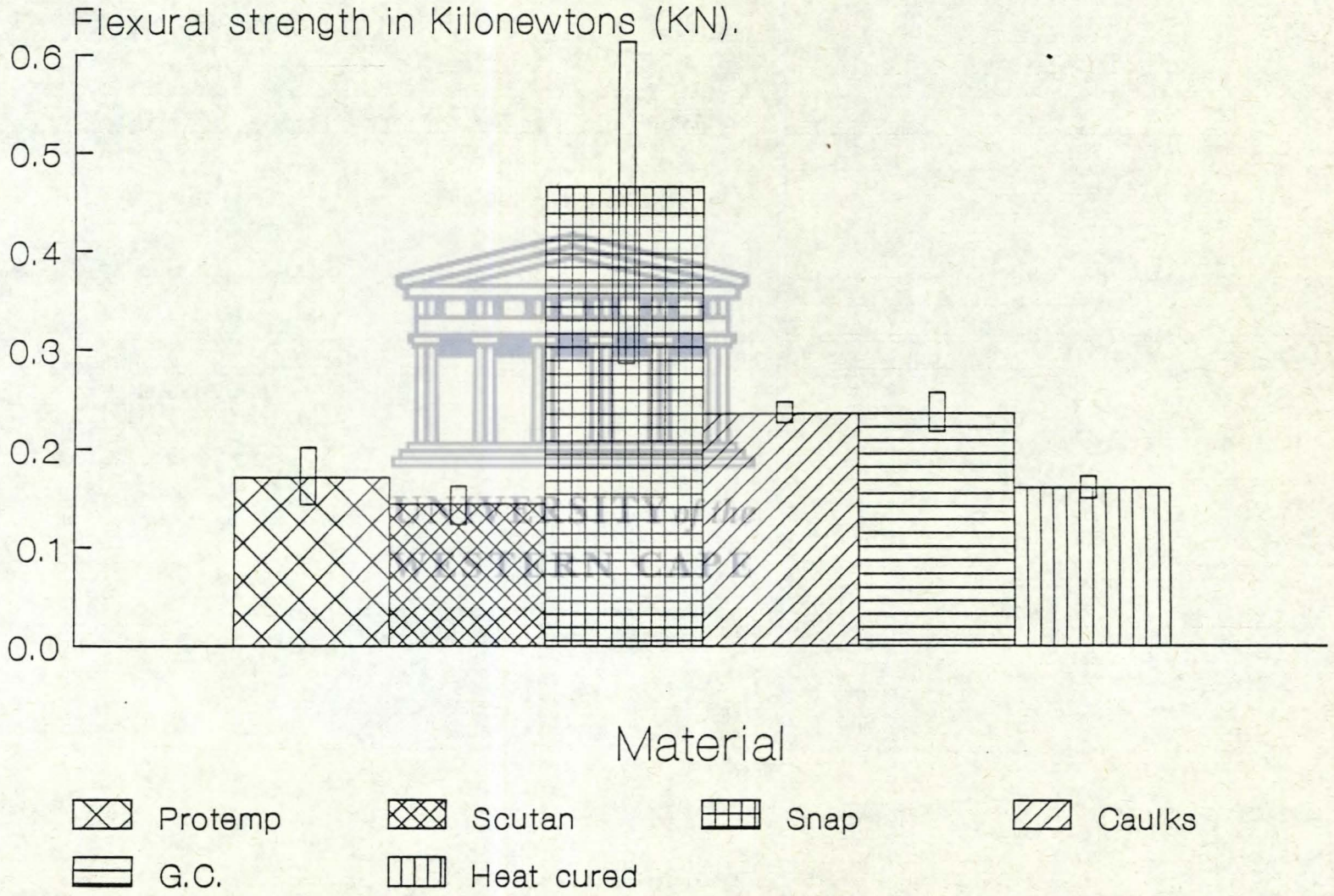


Figure 16 Means and standard deviations of all the materials tested.

Acrylics

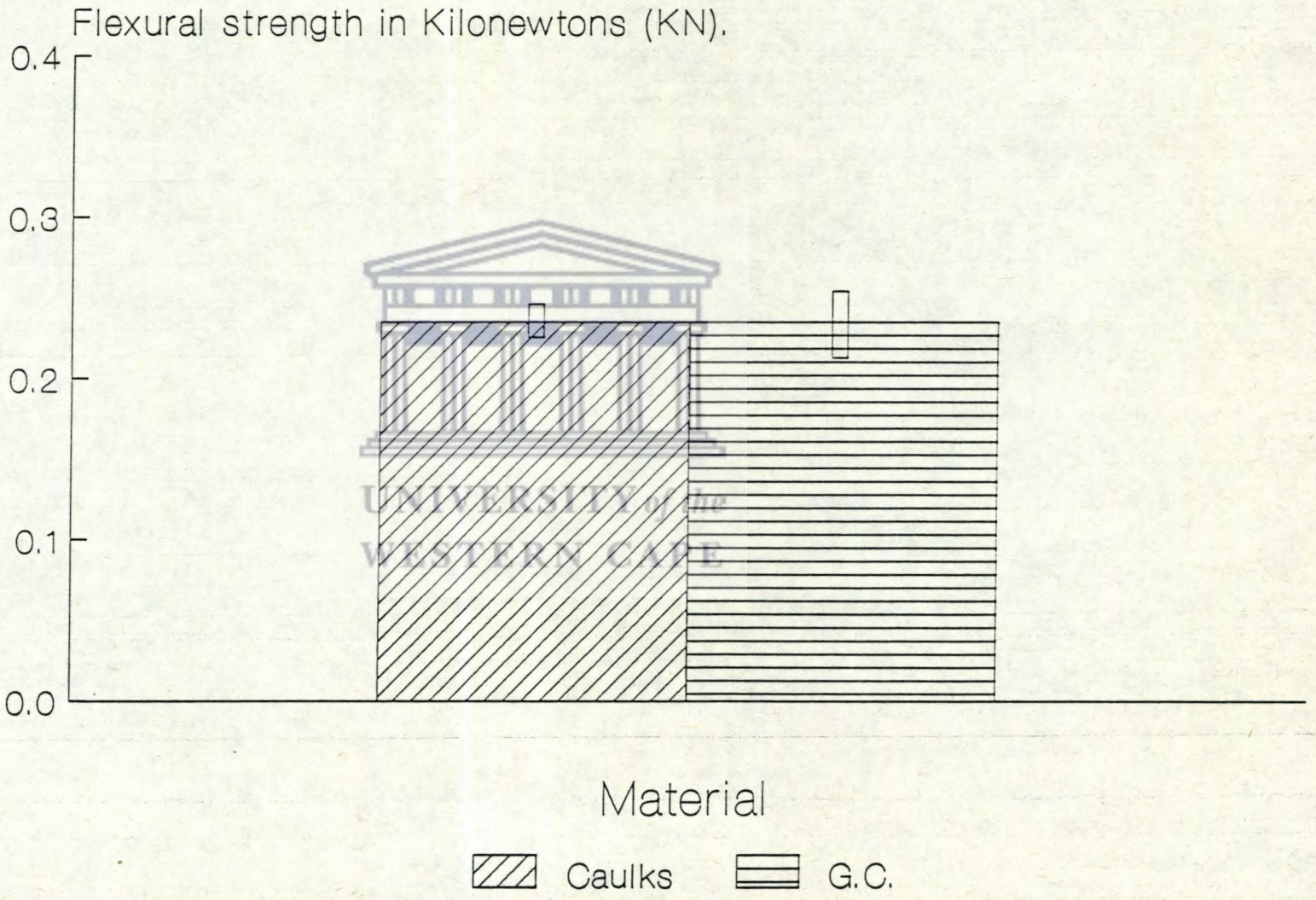


Figure 17 Comparison of the two Methylmethacrylates.

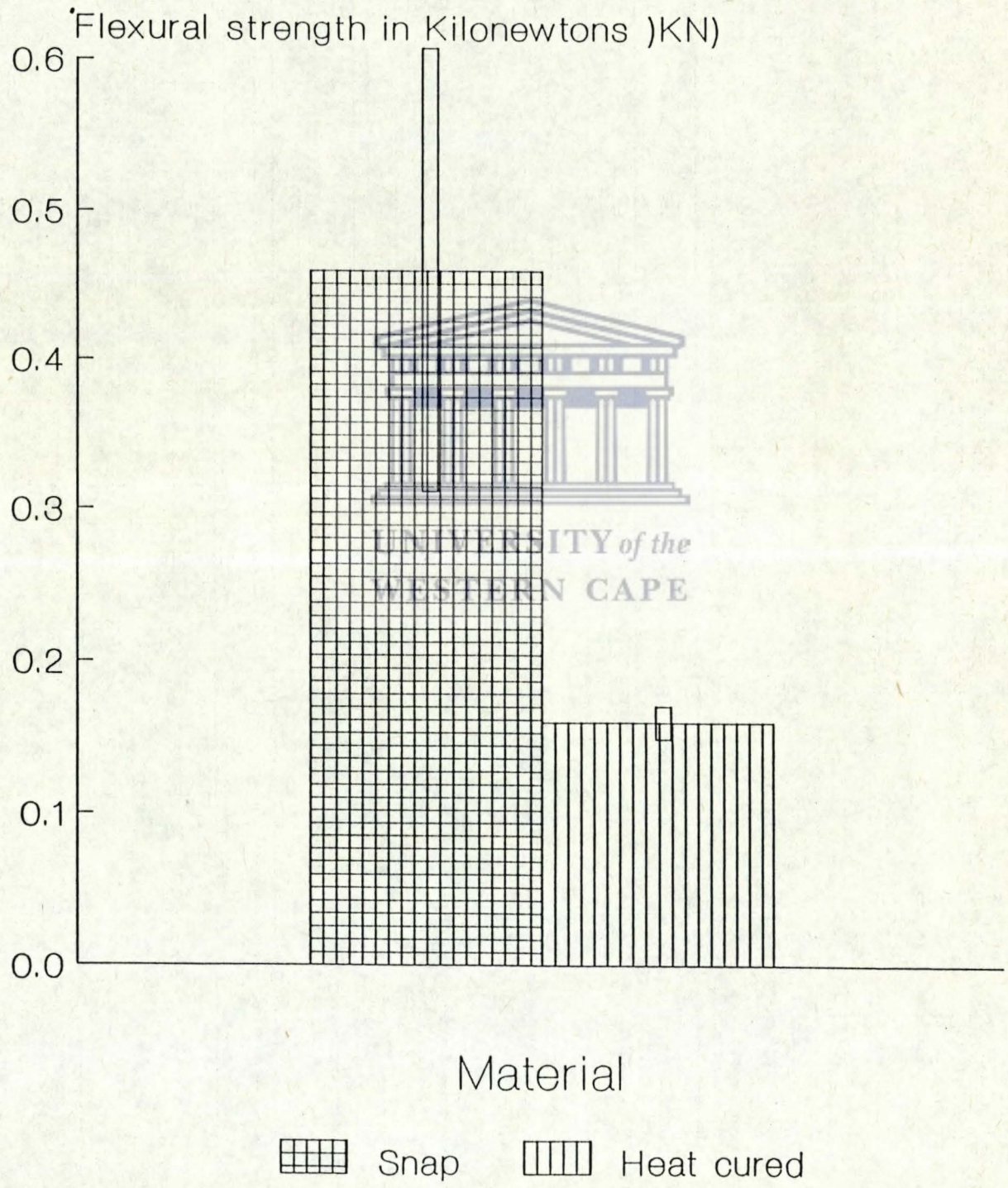


Figure 18 Comparison of the mean and SD of Snap and the Heat cured specimens.

Analysis of Variance (ANOVA) Table

Source of Variation	Sum of squares	Degrees of freedom	Mean sum of square = variance estimate	Variance Ratio F
Between groups	1749,02	4	437,26	31,41
Within groups	695,05	50	13,90	
Total	2444,07	54		

F test or Variance Ratio test = between groups variance estimate / within groups variance estimate

$$F = \frac{437,26}{13,92}$$

$$= \underline{31,41}$$

From F tables: P = 0,01 for F = 3,75 at 4 and 50 degrees of freedom

* for an F = 31,41 at 4 and 50 degrees of freedom

P < 0,001 which is highly significant

The mean square ("between groups") value and the mean square ("within groups") value represents the two independent estimates. If there is a statistically significant difference between the groups the mean square between the groups would be larger than the mean square within the groups.

$$\frac{\text{between groups}}{\text{within groups}}$$

This ratio is called the F ratio or the F value.

If the "between sample variation" is significantly greater, than the "within sample variation" as in this case of the 5 autopolymerizing materials tested, one should suspect that the samples are not in fact drawn from the same population but from populations whose mean values differ significantly.

Table 4 U - Values for all the autopolymerizing materials tested two at a time.

Protemp - Scutan	U = 22	Statiscally significant
Protemp - Caulk	U = 4	P < 0,05
Protemp - Snap	U = 19	" "
Protemp - G.C.	U = 4	" "
Scutan - Caulk	U = 4	" "
Scutan - G.C.	U = 4	" "
Scutan - Snap	U = 11	" "
Caulk - Snap	U = 22	" "
Caulk - G.C.	U = 47	Statistically not significant P > 0,05

From the table (Table 4) comparing the U values obtained after analysing two materials at a time it was found that a statistically significant difference existed between all the materials tested except between the older and the newer generation methylmethacrylates. That is there was no significant difference statistically between Caulk and G.C. at the 5% level. U = 47 p > 0,05.

From the results of these experiments SNAP was the strongest of the autopolymerizing materials tested.
A Mann-Whitney U test revealed a statistically significant difference existed between this material and the heat cured material. U = 14 p < 0,05.

A Student `t' test was also done to test for any significant differences between the two methylmethacrylates being tested.

This test also revealed that there was no statistically significant difference between the two methylmethacrylates (Caulks temporary bridge resin and G.C.'s unifast temporary resin).

Student `t' Test

t = 0,687 at p = 0,05 for 20 degrees of freedom

Caulk / G.C. t = 0,03

Statistically not significant

P > 0,05

5.3 SEM Results

Photographs of the fractured surfaces using the SEM were obtained and analysed for surface defects, voids and planes of polymerization (Figures 18 to 23).

5.3.1 Protemp (Figure 19)

There was a void clearly visible in the centre of the photograph. It was surrounded by an irregular periphery and was most probably due to air entrapment during packing and polymerization of the material.

5.3.2 Caulks temporary bridge resin (Figure 20)

This was an older generation methylmethacrylate and showed an uneven surface with numerous voids. Although all the materials were syringed into the mould prior to polymerization air entrapment seemed to be a common feature with the autopolymerizing materials.

5.3.3 Scutan (Figure 21)

This specimen also had an uneven surface with planes of polymerization. The surface exhibited ridges and valleys.

5.3.4 SNAP (Figure 22)

This material appeared to be reasonably homogenous. There was a void entrapped in the fracture face; however the periphery of the void was smooth when compared to that of the void in Protemp (figure 18).

5.3.5 G.C.'s Unifast (Figure 23)

This is a new generation methylmethacrylate. The material appeared to be homogenous but with definite crack lines or planes of polymerization. There was evidence of air entrapment within the specimen, yet it was also syringed into the mould.

5.3.6 Heat-cured specimens (Figure 24)

This surface appeared to be the most homogenous of all the materials viewed. There hardly appeared to be any air entrapment within the specimen.

FIGURE 19 - SEM photograph of Protemp. Void "V" shows surface defect. "A" is an artifact.

FIGURE 20 - SEM photograph of Caulks temporary brige resin. Numerous voids marked "V" present in the fracture face.

FIGURE 21 - SEM photograph of Scutan, showing ridges "R" and valleys "VA" within the specimen indicating planes of polymerization.

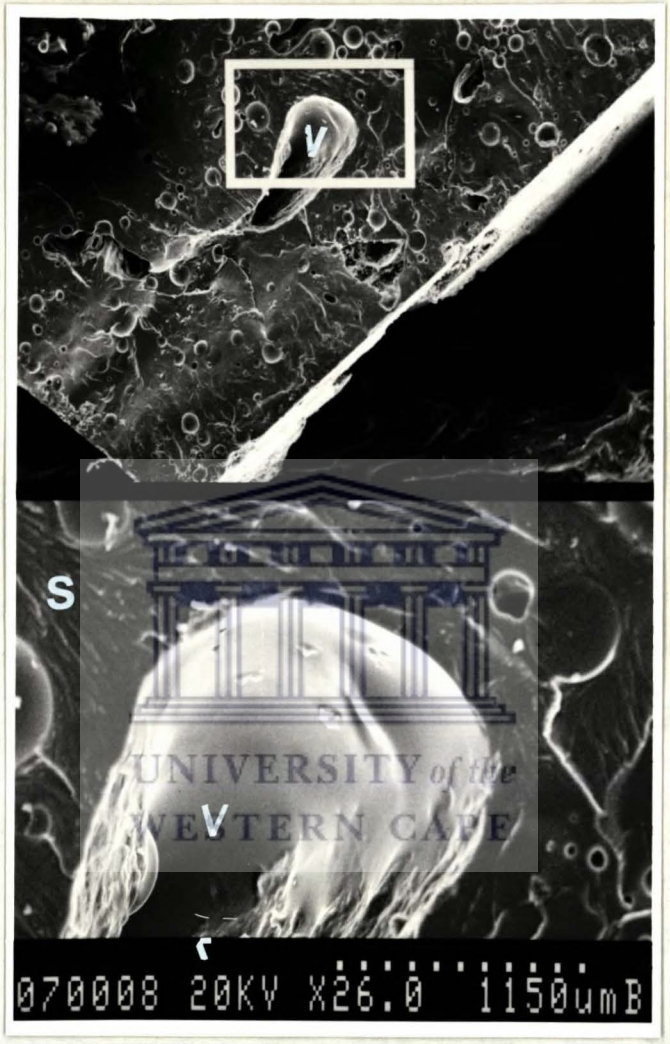


FIGURE 22 - SEM photograph of SNAP showing voids marked "V" and stress lines marked "S" in the fracture face.

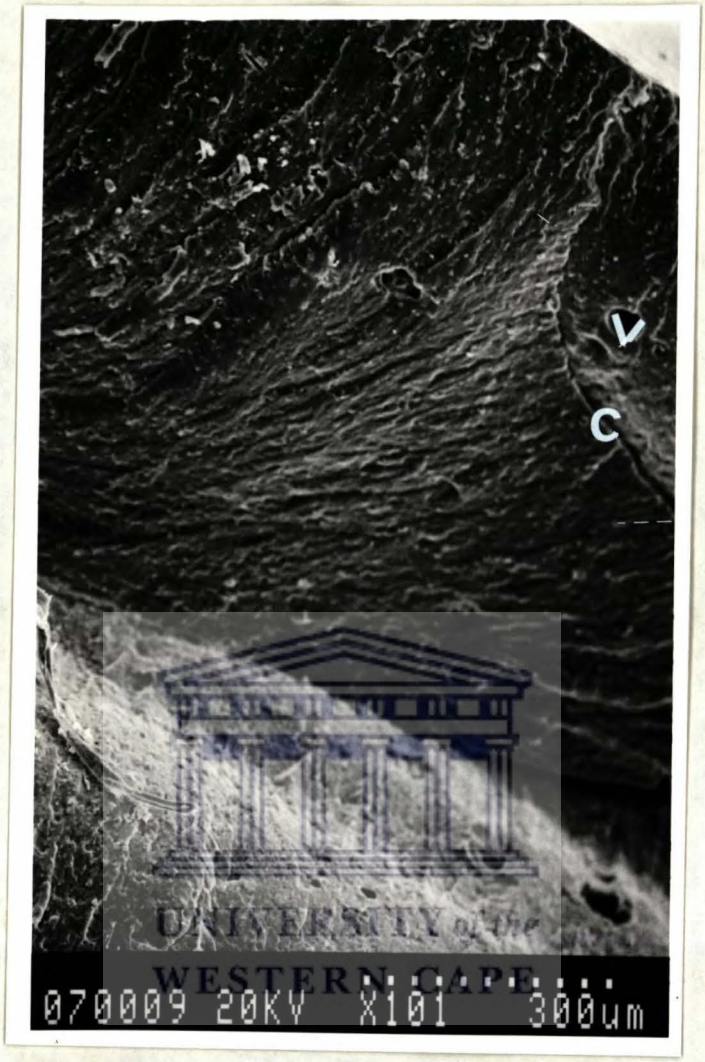


FIGURE 23 - SEM photogrpah of G.C.'s Unifast resin showing voids marked "V" and crack lines marked "C" (or planes of polymerization) in the fracture face.

FIGURE 24 - SEM photograph of a heat-cured specimen showing a homogenous surface.

CHAPTER 6 : DISCUSSION

6.1 Introduction

The materials tested in this study have all been utilised for the fabrication of provisional crowns and fixed partial dentures (bridges), thus making the results from this study clinically relevant.

The brass mould used to manufacture the specimens was specially designed for this experiment. The dimensions of the specimens from the brass mould were found to be consistently repeatable during the pilot study justifying the use of this mould for the fabrication of the test specimens.

Braden et al (1976) gave the dimensions of the specimens they used in their experiment but did not mention how the specimens were manufactured. Gregauff and Pryor (1986) used a metal mould for the fabrication of their test specimens.

The method used for the fabrication of the test specimens simulated the clinical situation in that all the autopolymerizing materials used were allowed to bench-cure for at least 20 minutes prior to being immersed in saline at 37°C for at least 24 hours.

The destruct test utilised in this experiment measured the flexural strength of the material. This flexural strength is a combination of the compressive, tensile and shear strength of the material and it accurately reflects the clinical situation where a force is applied to a fixed partial denture. El-Ebrashi, Craig and Peyton (1970) demonstrated stress distribution in a

model of a dental bridge (figure 25) showing compression, tension and shear stresses in action during simulated function.

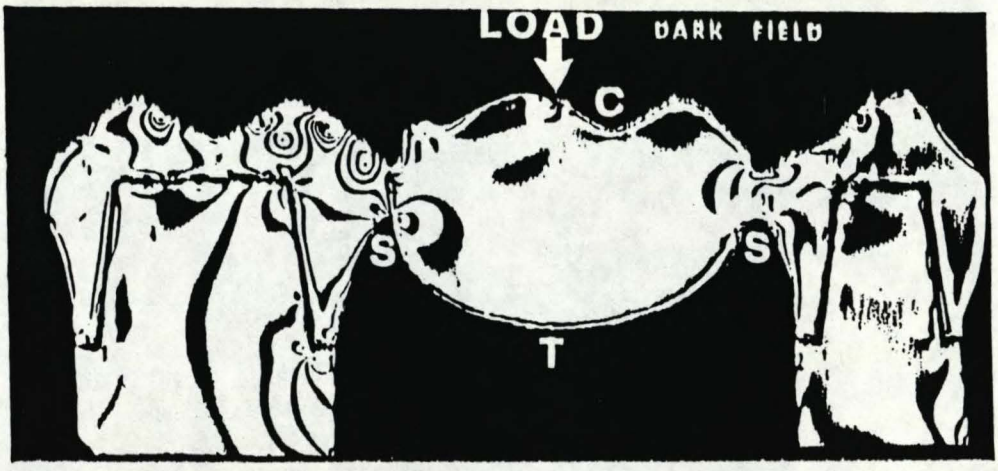


Figure 25. Stress distribution in a bridge model during function (from El-Ebrashi et al 1970).

A diagrammatic representation of the destruct test (figure 26) shows the clinical relevance of this test when compared to the bridge model of El-Ebrashi et al (1970).

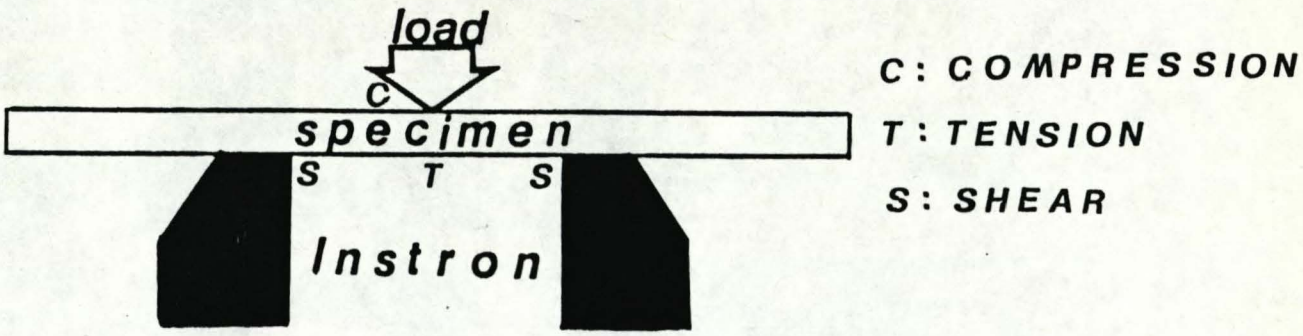


Figure 26. Diagrammatic representation of the destruct test used for the experiment.

6.2 Findings of this Study

From this study the greatest flexural strength was exhibited by the higher methacrylate SNAP. This was followed by the methyl methacrylates (Caulk and G.C's Unifast), then by the composite based Protemp and the heat-cured specimens with the epimine based resin Scutan showing the lowest flexural strength.

Snap had a mean flexural strength of 0,464KN and a standard deviation 0,16KN. To test for the degree of consistency of the specimens a co-efficient of variation was calculated. This is the standard deviation divided by the mean and converted to a percentage by multiplying the result by a 100. For Snap this co-efficient of variation was 34,78%. There were three specimens which were largely responsible for the large co-efficient of variation. The reason for the material behaving in this way is unknown. This may be a short-coming in the material and may be worth further investigation, under similar controlled, experimental conditions. However as a group the material exhibited the greatest flexural strength - it would rather bend than break.

The methylmethacrylates had a mean flexural strength of 0,235KN and a standard deviation of 0,015KN. This mean flexural strength was less than half that of the higher methacrylates. This difference is statistically significant but is of secondary importance in certain

clinical situations since from clinical experience the strength of these methylmethacrylates has proved to be adequate in the past.

The results for the individual specimens of these materials seems to have been much more consistent throughout the experiment. This is supported by the small standard deviation obtained with these materials. They have a co-efficient of variation ranging from 4,35% for Caulk to 8,70% for G.C., implying a high degree of consistency for the specimens within the two groups. There was however no significant difference in the flexural strength of the older and the newer generation methylmethacrylates and this indicates that there has not been much improvement in the strength of these materials since their introduction as provisional restorative materials in the 1940's.

The mean flexural strength for the composite based Protemp was 0,171KN with a standard deviation of 0,03KN. The standard deviation of this material implies its consistent behaviour during the experiment. It had a co-efficient of variation of 4,2%. The mean flexural strength of this material was approximately a third of that of the higher methacrylates. In a review by Vahidi (1985) the two greatest disadvantages of this material were its cost and its brittleness in long span bridges. This brittleness appeared to be very evident in this study and may be largely responsible for the poor display of strength of this material.

The mean flexural strength for the Epimine based resin Scutan was 0,144KN with a standard deviation of 0,02KN. Again this standard deviation implies the consistent nature of the material being tested. It had a co-efficient of variation of 5%. Also evident from these experiments was the brittleness of this material. It seemed not to have improved very much as regards strength since its initial introduction by Braden et al (1971).

The mean flexural strength for the heat cured specimens was 0,16KN with a standard deviation of 0,01KN. This implied a high degree of consistency with a co-efficient of variation of 6,25%. This material also displayed a high degree of brittleness and hence its low flexural strength in the experiment.As regards the destruct test the material did not compare very favourably to the higher methacrylate Snap, but this may be due to the brittleness of the heat-cured specimens.

The methylmethacrylates have fallen into disfavour recently. The monomer still has a pungent odour and can cause damage to both the pulp and the periodontal tissues if the operator is not careful. The temperature rise during setting is still a problem and although dependent to a large extent on the bulk of the restoration can cause irreversible damage to the pulp.

In a laboratory study involving 200mm specimens temperature increases of 10°C to 40°C above the oral temperature of 37°C were reported during setting of these resins (Craig, 1985). For this reason this group of materials is no longer recommended for the direct fabrication of provisional crowns and bridges.

However the different shades available in this group make it very useful for matching tooth shades. Their strength in the past was adequate and at one stage these were the only materials available for the fabrication of provisional crowns and fixed partial dentures. These materials can therefore still be used in the indirect method of fabricating provisional crowns and bridges in selected cases.

The higher methacrylates were manufactured to overcome the disadvantages of the methylmethacrylates. They were partly successful. They managed to remove the pungent odour and they managed to lower the curing temperatures but not to an optimum level. The highest curing temperatures recorded have ranged from 40°C to 60°C (Craig, 1985). This is not ideal but is acceptable for the direct fabrication of provisional restorations with utmost caution. However, there are disadvantages in that the ethyl and butyl methacrylates have a decreased glass transition temperature (McCabe, 1985). This diminishes their dimensional stability at the highest temperatures of the oral environment. The work of Crispin, et al (1980) comparing the materials used in

the direct method of making provisional restorations found SNAP, a higher methacrylate, to have the lowest marginal discrepancy, but even this discrepancy could be reduced significantly according to Barghi and Simmons (1976) if the provisional restorations were vented and relined at least once.

As with the methylmethacrylates, the higher methacrylates are available in different shades, and from the results of this study appear to be optimally suited for long term provisional crowns and bridges, provided sufficient care is taken during polymerization and relining of the provisional restoration.

The epimine based resin Scutan was manufactured as an answer to the problems encountered with the provisional restorations made from the methyl methacrylates and the higher methacrylates. The highest curing temperature recorded was between 42°C and 45°C (Braden et al, 1971) and this seemed to be ideally suited for the direct fabrication of the provisional restorations. However all the comparative strength tests conducted on this material showed it to be weaker than both the methyl and the higher methacrylates (Braden et al 1971 and 1976). Another disadvantage of this material was that it was only available in a single colour and this could result in an aesthetic problem especially in the anterior region of the mouth. However, clinically, the strength of this material may be sufficient in certain selected cases.

The latest material for the direct fabrication of the provisional restoration is the composite based Protemp. Of the materials used in the direct fabrication of the provisional restoration it has most successfully overcome the problem of a high curing temperature. The highest recorded curing temperature for this material ranged from 37°C to 40°C. It is also available in three shades and can therefore be used to match tooth shades quite adequately. The material handles exceptionally well but does not seem to be as strong as the higher methacrylates. It is not even as strong as the methylmethacrylates and this weakness in flexural strength may be a great drawback in longspan provisional fixed partial dentures used for prolonged periods in high stress bearing areas in the mouth. This finding was listed as one of the great disadvantages of this material by Vahidi (1985). The advantage of this material is the ease with which it can be repaired and added onto with both self-cured and light-cured composite resins (Goldstein, 1985).

From the review the heat-cured materials were found to be the most successful of all the materials tested as regards marginal adaptation, and heat of polymerization was not a problem since they were laboratory processed on a model (Crispin et al, 1981; Monday and Blais, 1985). However, from this study their flexural strength

was not as high as some of the autopolymerizing materials tested and this may be due to their brittle nature.

6.3 SEM Findings

The SEM findings were very revealing. All the autopolymerizing materials produced irregular surfaces (figures 19 to 24), yet all these materials were mixed according to the manufacturers instructions and syringed into the mould prior to polymerization. This uneven surface could only be due to what Crispin et al (1980) referred to as differences in polymerization in the various layers of the materials, thus forming planes of polymerization.

Kastenbaum (1982) had deduced from his clinical experience and his case histories that the heat-cured specimens were much stronger than the self-cured specimens because of their denser and therefore less porous nature. However the findings of this study partly support and partly contradict the views of Kastenbaum (1982).

From the SEM findings of this study the heat cured, laboratory processed specimens (figure 24) did exhibit the most homogenous surface of all the materials tested, but from the results it was evident that the heat-cured specimens were not stronger, as regards flexural strength as measured in this experiment, when compared to the auto-polymerizing resins.

Another finding from this study was the presence of voids in the fracture faces of the specimens, yet all the fracture faces were examined under a laboratory magnifying glass at the time of fracture and all the specimens with voids were excluded from the study. This finding emphasises the importance of the ultra-structural nature of the specimens in an experiment of this nature.

The presence of these voids could have been partly responsible for the poor performance of the materials in the experiments. It could also explain the brittleness of Protemp when this material was used in long span bridges (Vahidi, 1985).

In the case of Scutan (figure 21) the presence of the ridges and valleys may explain its poor performance in the destruct test. These ridges and valleys may be planes of polymerization which could act as crack propagators, facilitating the fracture of the specimen along this plane of polymerization.

The specimens made from SNAP would rather bend than break during the destruct tests. This ability to bend may be responsible for the high flexural strength exhibited by this material during this particular test Figure 27.

FIGURE 27 - Specimens made from SNAP - showing the characteristic bend before breaking.

On close examination of the higher magnification of the SEM photograph of SNAP (figure 22) there appeared to be stretch lines or lines of stress concentration around the void and this could have been due to the bending or stretching of the material prior to its fracturing.

CHAPTER 7 : CONCLUSIONS

The word "temporary" is misleading. These restorations should be called "therapeutic" or "provisional" since they are used in the interim period between the preparation of the teeth and the placement of the final restorations. This interim period can range from a few hours, to a few days, a few weeks and sometimes even as long as a few months. In some cases these restorations have been used for a year or even longer.

The materials tested in this study will all basically fulfill the requirements previously listed for a provisional restoration. However sometimes the need arises for a material with greater strength and in this regard there seems to be very little consensus in the literature. A provisional restoration which keeps breaking during an assessment period is not very good for both the patient-dentist relationship as well as for providing an optimum field for the placement of the permanent restoration.

This scant knowledge of the strength of the currently available provisional restorative materials together with the advent of numerous new materials with marvellous reports by the manufacturers as regards their strength, prompted this study.

The results from this study should not be seen in isolation but rather in relation to other studies, including the biological response studies.

Of the materials tested and under the conditions set out in this study SNAP, representing the higher methacrylates, had by far the highest flexural strength. This in no way made it the strongest of all the materials tested, it also did not make it out to be the sole material that could be used for provisional restorations to the exclusion of all the other materials. There are various factors which govern the selection of a particular material (see figure 1). Hopefully the results from this study read in conjuction with the biological response studies will enable the clinician to make that choice of material for any particular case a little easier.

This study has also shown that there is a statistically significant difference in the flexural strength of the higher methacrylate Snap and the heat cured material Biodent used in this study. Whether this statistically significant difference is of any clinical importance will still have to be determined.

The other conclusion from this study is that there is no significant difference in strength between the older generation (Caulks temporary bridge resin) and the newer generation (G.C.'s Unifast temporary resin) methylmethacrylates. These materials may have come a long way in the last 40 years or so but from this study it seems that there has not been much improvement in the strength of the materials as such.

REFERENCES

Adams, W.K. (1970). A temporary fixed partial denture. Journal of Prosthetic Dentistry 24:571-572.

Allan, J.C. (1982). Learning about Statistics. MacMillan South Africa (Publishers) (Pty) Ltd. 219-237.

Barghi, N. and Simmons, E.W. Jr.(1976). The marginal integrity of the temporary acrylic resin crown. Journal of Prosthetic Dentistry 36:274-277.

Braden, M. Causton, B. and Clark, R.L. (1971). An Ethylene - Imine derivative as a temporary crown and bridge material. Journal of Dental Research 50: 536-541.

Braden, M., Clark, R.L., Pearson, G.L. and Campbell Key, W. A (1976). New temporary crown and bridge resin. British Dental Journal 141:269-272.

Craig, R.G. (1985). Restorative Dental Materials. 7th Edition. The C.V. Mosby Company.

Crispin, B.J., Watson, J.F. and Caputo, A.A. (1980). The marginal accuracy of treatment restorations: A comparative analysis. Journal of Prosthetic Dentistry 44:283-290.

Daly, C.G. and Wilkinson, E.J. (1983). Use of a patient's natural crown as the pontic in a composite resin-retained temporary bridge. Australian Dental Journal 28:301-303.

Dahl, B.L. and Ostavik, J. (1976). Cytotoxicity of temporary crown and bridge materials. Journal of Oral Rehabilitation 3:341-347.

Davidoff, S.R. (1982). Heat processed acrylic resin provisional restorations: An in-office procedure. Journal of Prosthetic Dentistry 48: 673-675.

Doherty, M.J. (1979). Fabrication of an acrylic and metal band provisional restoration. Journal of Prosthetic Dentistry 41:109-112.

Dwork, H. (1981). Temporaries: A Preview of the Permanent Work Using the New Generation Self-Cure Resin Snap and a Vacuum Mould Matrix. New York Journal of Dentistry 51: 234-236.

El-Ebrashi, M.K., Craig, R.G., and Peyton, F.A., (1970) Experimental stress analysis of dental restorations. Part VII. Structural design and stress analysis of fixed partial dentures. Journal of Prosthetic Dentistry 23:177-186.

Federick, D.R. (1975). The processed provisional splint in periodontal prosthesis. Journal of Prosthetic Dentistry 33: 553-557.

Federick, D.R. (1975a). The provisional fixed partial dentures.Journal of Prosthetic Dentistry 34: 520-526.

Ferencz, J.L. (1981). Fabrication of Provisional Crowns and Fixed Partial Dentures Utilizing a "Shell" Technique. New York Journal of Dentistry 51: 201-206.

Fleisch, I, Cleaton-Jones, P., Forbes, M., Van Wyk, J. and Fat, C. (1984). Pulpal response to a bis-acryl-plastic (Protemp) temporary crown and bridge material. Journal of Oral Pathology 13:622-631.

Gregauff, A.G. and Pryor, H.G. (1986). Apparent fracture toughness of provisional resins for fixed prosthodontics. Journal of Dental Research, AADR, 65:Special issue, Abstract No.186 Page 190.

Goldstein G.R. (1985). Light-activated composite resin as an adjunct to the fabrication of fixed partial denture prosthesis. Journal of Prosthetic Dentistry 53:161-163.

Hunter, R.N. (1983). Construction of accurate acrylic resin provisional restorations. Journal of Prosthetic Dentistry 50:520-521.

Jordan, R.E., Suzuki, M. Sills, P.S., Gratton, D.R. and Gwinnett, J.A. (1978). Temporary fixed partial dentures fabricated by means of the acid-etch resin technique - a report of 86 cases followed for three years. Journal of the American Dental Association, 96:994-1001.

Kantorowicz, G.F. (1978). Bridgework for Cleft Palate Patients - Use of extended pontics. British Dental Journal, 145:335-336.

Kastenbaum, F. (1982). Laboratory processed provisional prostheses. New York Journal of Dentistry, 52:39-44.

Kinsel, R.P. (1986). Fabrication of treatment restorations using acrylic resin denture teeth. Journal of Prosthetic Dentistry 56:142-145.

Krug, R.S. (1973). Multiple uses of a plastic template in Fixed Prosthodontics. Journal of Prosthetic Dentistry 30:838-842.

Krug, R.S. (1975). Temporary Resins: Crowns and Bridges. Dental Clinics of North America 19:313-320.

La Barre, E.E. (1983). Fabrication of separate, adjacent provisional restorations. Journal of Prosthetic Dentistry, 49:631-632.

LaVecchia, L., Belott, R., DeBellis, L. and Naylor, W.P. (1980). A transitional anterior fixed prosthesis using composite resins. Journal of Prosthetic Dentistry 44:264-266.

McCabe, J.F. (1985). Temporary crown and bridge resins. In Anderson's Applied Dental Materials, Blackwell Scientific Publications.

Miller, S.D. (1983). The anterior fixed provisional restoration: A direct method. Journal of Prosthetic Dentistry 50:516-519.

Monday, J.J.L. and Blais, D. (1985). Marginal adaptation of provisional acrylic resin crowns. Journal of Prosthetic Dentistry 54:194-197.

Petersen, E.A., Phillips, R.W. and Swartz, M.L. (1966). A comparison of the physical properties of four restorative resins. Journal of the American Dental Association 73:1324-1336.

Phillips, R.W. (1982). In Skinners Science of Dental Materials, 8th Edition, W.B. Saunders Company.

Ruffino, A.R. (1985). Effect of steel strengtheners on fracture resistance of the acrylic resin complete denture base. Journal of Prosthetic Dentistry. 54:75-78.

Russell, M.D. (1986). The Role of Provisional Resorations. Dental Update, 13:425-437.

Tobias, R.S. (1980). Pulpal response to a temporary crown and bridge material in ferret teeth. Journal of Oral Rehabilitation. 7:387-393.

Vahidi. F. (1985). The Provisional Restoration. New York State Dental Journal. :208-211.

Wastall, D.G. (1987). Guidelines on the use and presentation of statistical methods. Journal of Dentistry , 15:2-5.

Weiner, S. (1983). Fabrication of provisional acrylic resin restorations. Journal of Prosthetic Dentistry 50:863-864.

APPENDIX

Appendix Table 1 Individual Protemp specimens

Order of Testing	Specimen No	mm	KN
55	1	6.25	.13
9	2	10.01	.20
22	3	9.34	.19
49	4	7.57	.15
33	5	9.79	.20
7	6	9.37	.19
30	7	10.28	.21
32	8	8.81	.18
31	9	7.45	.15
28	10	7.32	.15
36	11	7.90	.16
Sample Totals:		94.09	1.88
Sample Mean:		8.55	.17
Standard Deviation:		1.32	.03

Appendix Table 2 Individual Scutan specimens

Order of Testing	Specimen No	mm	KN
27	23	6.36	.13
45	24	5.90	.12
47	25	7.37	.15
19	26	6.96	.14
52	27	8.27	.17
3	28	8.25	.17
5	29	6.94	.14
40	30	8.90	.18
15	31	8.29	.17
38	32	5.93	.12
6	33	6.10	.12
Sample Total:		79.27	1.59
Sample Mean:		7.21	.14
Standard Deviation:		1.08	.02

Appendix Table 3 Individual Snap specimens

Order of Testing	Specimen No	mm	KN
50	34	23.62	.47
2	35	27.01	.54
39	36	26.36	.53
37	37	26.98	.54
41	38	6.60	.13
29	39	27.96	.56
23	40	27.38	.55
14	41	28.40	.57
25	42	26.42	.53
42	43	7.39	.15
8	44	27.02	.54
Sample Total:		255.14	5.10
Sample Mean:		23.19	.46
Standard Deviation:		8.10	.16

Appendix Table 4 Individual Caulk specimens

Order of Testing	Specimen No.	mm	KN
46	12	11.37	.23
11	13	11.68	.23
16	14	11.43	.23
20	15	12.43	.25
54	16	11.46	.23
34	17	11.85	.24
51	18	11.51	.23
26	19	10.62	.21
35	20	11.36	.23
10	21	13.04	.26
24	22	12.47	.25
Sample Total:		129.22	2.58
Sample Mean:		11.75	.23
Standard deviation		.67	.01

Appendix Table 5 Individual G.C. specimens

Order of Testing	Specimen No.	mm	KN
43	45	13.36	.27
53	46	12.02	.24
13	47	12.48	.25
4	48	12.25	.25
44	49	11.12	.22
12	50	11.33	.23
17	51	12.09	.24
48	52	11.29	.23
1	53	11.12	.22
18	54	10.80	.22
21	55	11.25	.23
Sample Total:		129.11	2.58
Sample Mean:		11.74	.23
Standard Deviation:		.77	.02

Appendix Table 6 Individual Heat cured specimens

Order of Testing	Specimen No.	mm	KN
56	56	7.80	.16
57	57	7.92	.16
58	58	9.02	.18
59	59	9	.18
60	60	6.97	.14
61	61	7.73	.15
62	62	7.77	.16
63	63	7.06	.14
64	64	7.06	.14
65	65	7.24	.14
66	66	8	.16
Sample Total:		85.57	1.71
Sample Mean:		7.78	.16
Standard Deviation:		.71	.01

The Mann-Whitney U test for Caulk and G.C. Unifast

From the results for Caulk and G.C. the values were ranked with all the values for Caulk designated N1 and those for G.C. N2

Appendix Table 7: Calculation of the "U" Value

Rank	Material	Value	Rank	Material	Value
1	N1	0,2124	12	N1	0,2302
2	N2	0,2160	13	N1	0,2336
3	N2	0,2224	14	N1	0,2370
4	N2	0,2224	15	N2	0,2404
5	N2	0,2250	16	N2	0,2418
6	N2	0,2258	17	N2	0,2450
7	N2	0,2266	18	N1	0,2486
8	N1	0,2272	19	N1	0,2494
9	N1	0,2274	20	N2	0,2496
10	N1	0,2286	21	N1	0,2608
11	N1	0,2292	22	N2	0,2672

R1 represents the sum total of the rankings for materials N1 and R2 represents the sum total of the rankings for material N2.

To calculate the U-value for the Mann-Whitney U test as applied to G.C. and Caulks temporary bridge resin the following formula was used:-

$$U1 = N1 \times N2 + \frac{N1\ (N1 + 1)}{2} - R1$$

$$= 11 \times 11 + \frac{11\ (11 + 11)}{2} - 136$$

$$= 121 + 62 - 136$$

$$= \underline{47}$$

To calculate the other U i.e. U2

$$U2 = N1 \times N2 - U$$

$$= 11 \times 11 - 47$$

$$= 121 - 47$$

$$= 74$$

The lesser of the 2 U values is used and if this value exceeds the U value for N1=11 and N2=11 at a significance level of p=0,05 than the difference between the two materials being tested is statistically <u>not significant</u>.

Appendix Table 8 Mann-Whitney U test between SNAP and Heat-cured specimens

RANK	MATERIAL	VALUE	RANK	MATERIAL	VALUE
1	N1	6,60	12	N2	9,00
2	N2	6,97	13	N2	9,02
3	N2	7,06	14	N1	23,62
4	N2	7,06	15	N1	26,36
5	N2	7,24	16	N1	26,42
6	N1	7,39	17	N1	27,01
7	N2	7,73	18	N1	27,02
8	N2	7,77	19	N1	27,38
9	N2	7,80	20	N1	27,96
10	N2	7,92	21	N1	28,40
11	N2	8,00	22	N1	29,98

$R1 = 1 + 6 + 14 + 15 + 16 + 17 + 18 + 19 + 20 + 22 = \underline{169}$

$R2 = 2 + 4 + 5 + 7 + 8 + 9 + 10 + 11 + 12 + 13 = \underline{84}$

$$U = N1 \times N2 + \frac{N1\,(N1 + 1)}{2} - R1$$

$$= 11 \times 11 + \frac{11(11 + 1)}{2} - R1$$

$$= 121 + 62 - 169$$

$$= 183 - 169 \quad \text{---> } U1 = \underline{14}$$

$$U = N1 \times N2 - U1$$

$$= 11 \times 11 - 14$$

$$= 121 - 14 \quad \text{---> } U2 = \underline{107}$$

The lesser of the two U values is used to claim statistical significance. At the 5% level a U value less than 30 for N1 = 11 and N2 = 11 implies a statistically significant difference between the heat cured specimens and SNAP.

SUMMARY

One of the requirements of an ideal provisional crown and bridge material is that it must be strong enough to resist fracture and wear during function. According to Russell (1986), the strength of a material is one of the most important factors in a provisional restoration especially if that restoration was going to be used for a prolonged period. The purpose of this study was to determine the strength of various auto-polymerizing provisional crown and bridge materials under controlled, laboratory conditions, then to compare the strongest of these auto-polymerizing materials with a heat-cured provisional restoration.

Five resins representing the four major groups of autopolymerizing resins were tested: two methylmethacrylates (Caulks and G.C.); a polyvinyl ethylmethacrylate (Snap); an epimine based resin (Scutan); and a composite based resin (Protemp). The heat-cured resin tested was Biodent.

Eleven specimens of each material were prepared using a split-cast brass mould. The load required to fracture the specimen on an Instron machine was recorded.

Applying the ANOVA test to the data collected revealed a significant difference in the materials being tested. The polyvinyl ethylmethacrylate (Snap) demonstrated the greatest strength of all the resins tested. The epimine based resin Scutan and the composite based Protemp were the weakest of

the autopolymerizing resins with the two methylmethacrylates exhibiting a flexural strength between the strongest and the weakest resins.

To test for differences between two materials at a time the Mann-Whitney U test was applied to the data. There was a significant difference between all the materials tested except between the older (Caulk) and the newer generation (G.C.) methylmethacrylate. There was also a significant difference between the strongest autopolymerizing resin (Snap) and the heat-cured (Biodent) resin.

OPSOMMING

Een van die vereistes van 'n ideale materiaal vir 'n tydelike kroon en brug is die breuk en slyfweerstand daarvan gedurende gebruik. Volgens Russell (1986) is die sterkte van 'n materiaal een van die belangrikste faktore in 'n tydelike herstelling, veral as daardie restorasie vir 'n lang tydperk gebruik gaan word. Die doel van hierdie studie was om te bepaal watter van die self-polimeriserende tydelike kroon-en brugmateriaal die sterkste is onder beheerde laboratoriumtoestande, en om die sterkte van hierdie materiaal te vergelyk met 'n hitte-verharde, tydelike restorasie.

Vyf harse wat die vier mees belangrike groepe van self-polimeriserende harse verteenwoordig is getoets: twee metielmetakrilite (Caulk en G.C.); 'n poliviniel-etielmetakriliet, (Snap); 'n epimine-basies-hars (Scutan) en 'n gemengde basies hars (Protemp). Die hitteverharde hars wat getoets is, is Biodent se kroon-en brugmateriaal wat deur De Trey in Wes-Duitsland vervaardig word.

Elf monsters van elke materiaal is gemaak d.m.v.'n gesplete gietblok wat spesiaal vir die proefneming vervaardig is. Die lesing van die druk wat nodig was om die monsters op die Instronmasjien te laat breek is geregistreer.

Die dataverwerking met die ANOVA toets het 'n betekenisvolleverskil getoon tussen die materiale wat getoets is. Die poliviniel-etielmetakriliet (Snap) was die

sterkste. Die epimine-basies hars (Scutan) en die gemengde basies hars (Protemp) was die swakste, terwyl die twee metielmetakriliet harse van gemiddelde sterkte was.

Om verskille tussen twee materiale vas te stel is die Mann-Whitney U-toets gebruik. Die uitslag het bewys dat daar 'n betekenisvolle verskil was tussen al die materiale wat getoets is behalwe tussen die ouer ontwikkelde metielmetakriliet (Caulk) en die jongsontwikkelde tipe (G.C.). Die Mann-Whitney toets het ook bewys dat daar a betekenisvolle verskil is tussen die sterkste van die self polimeriserende hars (Snap) en die hitteverharde hars (Biodent).