The dimensional distortion of acrylic resin denture bases subjected to different dual cure materials and methods

---

Dr MG Thokoane

A research report submitted to the School of Oral Health Science, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Dentistry in the field of Prosthodontics.

Johannesburg, 2013

DECLARATION

I, Meriting Gladys Thokoane declare that this research report is my own work. It is being submitted for the degree of Master of Dentistry (Prosthodontics) of the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

……………………………..

Meriting Gladys Thokoane

06 December 2013

ABSTRACT

Background: The majority of edentulous patients are unable to afford anything other than mucosa-borne complete dentures, but the conventional methods of complete denture fabrication can be lengthy and expensive. Simplified techniques have been proposed to reduce the number of clinical visits as well as the laboratory time and costs. One such technique has advocated making the final heat-cured acrylic resin denture base after the first visit, which then requires a second processing cure for the artificial teeth. This dual-cure has been reported to cause distortion of the previously cured denture base.

Purpose: To measure the amount of linear and three-dimensional distortion of an acrylic resin maxillary denture base following an additional curing cycle using different processing methods.

Method and Materials: A standardised method was developed for fabricating a maxillary denture base with measuring pins , as well as a standardised method for waxing an arch of teeth to the base. The pins were used to make three-dimensional measurements using a Reflex Microscope. The resins used were from the same manufacturer. Four dual cure methods of varying temperature and time were used: 1. Place flask in boiling water for 20 minutes, remove and plunge into cold water for 20 minutes; 2. Place into cold water, heat up to 70°C, leave for 1 hour, remove and bench cool; 3. Place into cold water, bring to 72°C for 8 hours and bench cool; and 4. Place in cold water, bring to the boil for 40 minutes, bench cool for 45 minutes, then plunge into cold water for 20 minutes. For each method five models were fabricated, to give a total of 20 models.

Results: Although there was an overall distortion of all denture bases following a second cure, the linear and 3D differences were not statistically significant between and within the different dual cure methods tested. The mean percentage changes measured were translated into real changes in distances or angles between the pins, in order to ascertain the clinical relevance of these changes, for if they are too great, the distortion of the denture base will exceed the resilience of the mucosa as well as disrupt the peripheral seal, and the denture base will not be retentive. The largest mean change was seen in the three-dimension distance between the innermost pins in the posterior palate, but this was only 1.3mm. This also showed the worst change of all measurements, but it was still only 2.0mm.

Conclusions: With the adaptive nature of the denture-supporting tissues, the changes described are unlikely to have any clinical significance. Although only one brand of denture base resin was used, it is representative of the modern rapid-cure resins, and so rapid cure methods can be advocated when a dual cure is required.

ACKNOWLEDGEMENTS

I am grateful to Mr G Kruger, Chief Dental Technician at the Wits Oral Health Centre, and Mr H Moyane and E Mamokgere for their assistance with the technical aspects of this study.

I am also grateful to Dr Petra Gaylard for the statistical analyses and explanations.

Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Mucosa-borne complete dentures are the only treatment available for edentulous patients who cannot afford or may not want the alternative of implant dentistry (Jacob, 1998). Complete denture therapy will therefore remain an invaluable treatment modality for the edentulous patient.

Data on the prevalence of edentulism is said to be inconsistent and unreliable (Owen, 2004). Carlsson & Omar (2009) suggested that there may be a downward trend in edentulism, but that such a trend was region-specific, and that those factors which lead to eventual tooth loss are complex and involved disease and non-disease entities.

The Academy of Prosthodontics of South Africa (2012) reported that 11% of the South African population was edentulous; this translates into more than 1, 6 million people requiring oral rehabilitation with mucosa-borne complete dentures or implant supported prostheses.

At the Wits Oral Health Centre there is a waiting list of more than three years for patients requiring complete denture therapy. Patients wait on the list as they cannot afford treatment elsewhere. We therefore continue to try and develop cost-effective methods (guided by prosthodontic principles) to meet this demand without compromising quality.

1.2 Literature review

The need to understand the clinical and laboratory processes necessary to construct complete dentures with minimal errors and cost effectiveness (time & resources) is the reason complete denture construction is still under scrutiny. The fabrication of complete dentures involves a number of steps both in the clinic and the laboratory. It is necessary for each one of these steps to improve or maintain the accuracy of the previous stage.

From the initial stages of impression making the rationale is to relate the basal seat and the denture base extensions to the underlying edentulous ridge as accurately as possible (Jacob, 1998). Throughout the procedure, the denture base must relate to the underlying anatomical structures in a similar manner, until completion. There are steps which are potential sources of inaccuracies, such as casting of the master model, construction of the trial (usually wax) base and its transformation into a permanent base (Langer, 1981).

Establishing maxillomandibular relationship records is a critical step which will, using anatomical landmarks, determine the horizontal and vertical relationship of the jaws, and the anterior and posterior tooth positions. These factors will influence not only the aesthetics but also the retention and stability of the denture during function, hence the need for these records to maintain their accuracy.

Graser (1978) reported that the accuracy of maxillomandibular records was directly related to the accuracy of the bases with which the records were made. To minimise inaccuracies the recording bases must be able to evenly distribute the load created when the maxillomandibular relationship is being established; this load includes the reaction of the underlying resilient mucosa (Langer, 1981). The use of acrylic bases to record jaw relations will enable accurate maxillomandibular records as well as reduce processing errors by providing a rigid, stable, and retentive base for the wax occlusal rims (Langer, 1981).

When acrylic bases are used, then denture construction is divided into two stages, with the denture base undergoing two, instead of one polymerisation process. Despite the improved accuracy of the jaw relation records and the reduced occlusal discrepancies associated with the use of acrylic bases (Langer, 1981), this method has been criticised on the basis that the second cure will lead to distortion and loss of fit of the base (Yeung et al, 1995).

Poly (methyl methacrylate) (PMMA) was first used as a denture base material in 1935 (Harrison et al, 1993). PMMA is a heat-activated denture base resin, and the source of the heat may be a water bath; chemical activation by adding a cross-linking agent (such as g*lycol dimethacrylate*) to the monomer at room temperature; or microwave energy (Phoenix, 2003).

The processing deformation that occurs during denture polymerisation is reported as the material’s major disadvantage (Chen et al , 1988). Lechner and Lautenschlager (1984) described this deformation as an overall contraction which requires the adjustment of both the base and occlusal surfaces of the finished denture. These processing changes of PMMA are attributed to polymerisation shrinkage, an inherent characteristic of this material.

When heated, each molecule occupies more space than its actual volume due to its thermal motion (Darvell, 2009). Therefore the ratio of polymer to monomer, as well as processing temperatures (heating and cooling) of denture bases will affect the amount of denture distortion. Heating of a denture base during processing occurs at different rates due to the variation in chain lengths of the molecules; as a result polymerisation shrinkage is not uniform throughout the denture base. These qualities of the material mean that there will always be residual stresses after cooling of the denture base (Darvell, 2009), and these are thought to be a source for potential subsequent dimensional distortion during the second cure (Craig, 1980 cited in Al-Hanbali et al, 1991).

The traditional method for processing heat activated denture base resin is the pressure/ compression moulding technique where a wax denture base is replaced by PMMA. The polymerisation process is activated by placing the packed flask in water and increasing the temperature. It is an exothermic reaction and the heat generated may affect the properties of the final dentures (Phoenix, 2003). The plaster investing the cast and resin as well as the resin are said to have low thermal conductivity, therefore the heat produced by the reaction inside the flask cannot be dissipated such that the internal temperature may reach 130°C and exceed the boiling point of the monomer of 100.8° C (Phoenix, 2003 and Darvell, 2009).

Benzoyl peroxide in the powder component of PMMA is responsible for initiating the polymerisation process. When the polymer and monomer components are combined and exposed to heat (above 60°C), benzoyl peroxide molecules decompose and yield free radicals which then react with available monomer. Should the internal temperature within the flask exceed the boiling point of the monomer, any unreacted monomer will be boiled out and generate porosity in the finished denture. Darvell (2009) further reported that the stresses induced by the excessive internal temperature hike may lead to denture base distortion.

To avoid internal temperature spiking, the temperature of the heat source should be controlled directly, and/ or indirectly by controlling the time of exposure to the heat source. It is these factors which are manipulated to determine the shortest time necessary for optimum polymerisation and without distorting the denture base.

Brewer (1963) reported that the greatest deformation of the denture base was recorded after the first curing cycle, and that a second cure at 60°C resulted in insignificant deformation. The author did not report the length of time necessary for the process, nor the cooling method used. The recommended temperature should, however, be less than the temperature used for the primary cure, so as to minimise distortion due to residual stress release. This concept was further supported by Graser (1978) who also advocated a longer second cure at a reduced temperature (55°C-60°C for 12 hours), compared with the primary cure, which was achieved at a higher temperature and reduced time (75°C - 80°C for 9 hours). Once again the author did not provide data to support these processing guidelines, and reported a cooling method without a specific cooling period.

Polukoshko et al (1992) tested three curing temperatures and recommended that the second cure should be at 75°C - 80°C for 9 hours. They reported that a second cure at a temperature lower than they used would lead to an insufficient cure of the denture teeth supporting acrylic with reduced hardness of the material, as well as an increased amount of residual monomer content. They also reported a trend for greater denture base distortion with increasing temperatures but only in the range of 0.01 to 0.03mm, and that this would not significantly affect the clinical quality of the maxillary denture.

Yeung et al1995) examined the linear dimensional change of heat cured acrylic in a two-stage processing technique and recommended a second cure at 72°C for 8 hours.

Polymerisation of PMMA using a microwave oven is also possible; a conventional microwave oven can be utilised but non-metallic flasks specifically designed for this method are required. Darvell (2009) cited the advanced speed with which polymerisation occurred as an advantage for using microwave energy. Kimura et al (1984) cited in Al-Hanbali et al (1991) reported that using microwaves resulted in homogenous heating of the investing plaster as well as the denture resin, and this resulted in a reduction of internal stresses in the processed denture.

Al-Hanbali et al (1991) compared the dimensional stability of PMMA denture bases subjected to double processing with microwave energy and conventional water bath techniques. The second cures tested were 12 hours at 65°C (conventional processing), 20 minutes at 100°C (rapid processing) for the water bath methods; and 25 minutes at 65W for the microwave method. These authors concluded that microwave energy processing yielded significantly reduced dimensional change when compared with rapid processing in boiling water. The differences were, however, not considered to be clinically significant and only one cooling method was used in this study and only one material was investigated. The only significant factor was the time difference between the two techniques; according to their findings microwave energy can yield 36 dentures in the time it takes for the conventional water bath method to yield a single denture. The time difference between the rapid processing and the microwave processing methods was negligible.

Cold-cure or autopolymerisation resins do not require the application of thermal energy to initiate material polymerisation. Instead of heat, chemical activators are added to the material and polymerisation can be completed at room temperature (Darvell, 2009). The processing is similar to that for heat cured resins, except that the flask is left at room temperature.

The fluid or pourable resins are also chemically activated, but the mixture yields a low viscosity material which can be poured into a mould subjected to increased atmospheric pressure. This technique also requires a specially designed flask, and a mould of the denture teeth on the cast is made in the flask by pouring reversible hydrocolloid investing medium over the cast with teeth (Phoenix, 2003).

Once the investing medium is set the cast with teeth is retrieved; vents and sprues are then cut to introduce the resin into the mould cavity with the flask sealed. The wax supporting the teeth is then boiled out and the teeth are positioned into their positions within the hydrocolloid investing medium as well as the acrylic base. The flask is then closed and pourable resin is poured into the mould cavity through the sprues to replace the lost wax which had supported the denture teeth. At room temperature the flask is then placed in a pressure pot and allowed to undergo polymerisation for 45 min.

Although distortion has been recorded in these studies, none have reported dimensional changes with significant clinical implications.. At the Wits Oral Health Centre it is prescribed that the laboratories which process our complete dentures follow a strict protocol during the second cure to minimise denture base warpage. Our instructed protocol for the second cure was an hour long at 70°C followed by bench cooling. However, it was found that the actual process used involved two rapid boil cycles, and despite the theoretical disadvantage of this, very few if any clinical complications arose from this cycle.

The conventional fabrication of complete dentures is a lengthy process with a minimum of six appointments. This conventional method of denture fabrication was dictated by the materials available, and also by the fact that the clinical and laboratory components of denture fabrication were viewed as separate entities. The CD4 technique (Owen and MacEntee, 2012) has challenged this norm; it aims to provide the patient with quality prostheses in three visits. This reduces the time as well as the cost of making complete dentures. The CD4 technique is an example of 'appropriatech', a concept which aims to use cost effective materials and methods without sacrificing a minimum acceptable protocol (MAP) in accordance with prosthodontic principles (Owen, 2006). Such a technique can be enhanced by the knowledge of the best combination of materials in terms of the stability of prostheses, as well as the minimum amount of time necessary to process this combination.

This study evaluated the null hypothesis that there is no distortion of an acrylic resin maxillary base following an additional curing cycle when using different processing methods and materials.

CHAPTER 2: AIMS AND OBJECTIVES

2.1 Aim

The aim of this research is to measure the amount of three-dimensional distortion of an acrylic resin maxillary base following an additional curing cycle using different processing methods

2.2 Objectives

- To establish a standardised method of fabricating a maxillary denture base with suitable markers for measurement in a Reflex Microscope.
- To use a variety of curing methods for the dual cure process.
- To measure the linear and three-dimensional distortion of the denture base following the dual cure (before and after de-flasking).

CHAPTER 3: METHODS AND MATERIALS

3.1 Standard models and denture bases

Denture bases and casts were made from standardised moulds for each component. The heat cured bases were made from a single mould; this mould also had markings of where the reference pins (Pindex, Dentaurum Sweden) would be positioned on the base. In a similar manner a mould for setting teeth was fabricated using the same make and mould of teeth in each case. All moulds, models, and bases were fabricated by the same person.

The acrylic bases were processed (using Sure acrylic clear, Kemdent UK) by placing the flask in cold water, bringing it to a boil and maintaining it at that temperature for 30 minutes. The base was then bench cooled for 45 minutes and plunged into cold water for 20 minutes.

After de-flasking and finishing, each denture base had an identical arch of teeth waxed onto it using the standardised mould (figure 1), and underwent a second processing, to replace the wax with acrylic.

Fig. 1 Silicone mould for waxing the teeth to the cured base

The second cure was subject to the following methods:

1. Place flask in boiling water for 20 minutes, remove and plunge into cold water for 20 minutes.
2. Place in cold water, allow the water to heat up to 70°C and leave for 1 hour, remove and bench cool
3. Place into cold water bring water to 72°C for 8 hours and bench cool
4. Place in cold water, bring to the boil for 40 minutes and bench cool for 45 minutes, and then plunge into cold water for 20 minutes.

The same heat curing acrylic (Sure acrylic, Kemdent UK) was used for all methods.

3.2 Positioning of reference points

Dowel pins were incorporated into the denture base and the denture at agreed landmarks. These pins served as points from which to measure before and after the second cure.

Six dowel pins were positioned on the polished surfaces of the denture: two 1 cm away from the gingival contours of the second molars on the palate; one in the incisive papilla; two in the buccal flange opposite the second molars; and one at the labial flange between the central incisors (figure 2).

The dowel pins are produced from a single mould, which gives them a standard size and shape with adequate surface anatomy. They are serrated, which prevented dislodgement during processing, and they are made from brass which is not affected by the curing temperatures used.

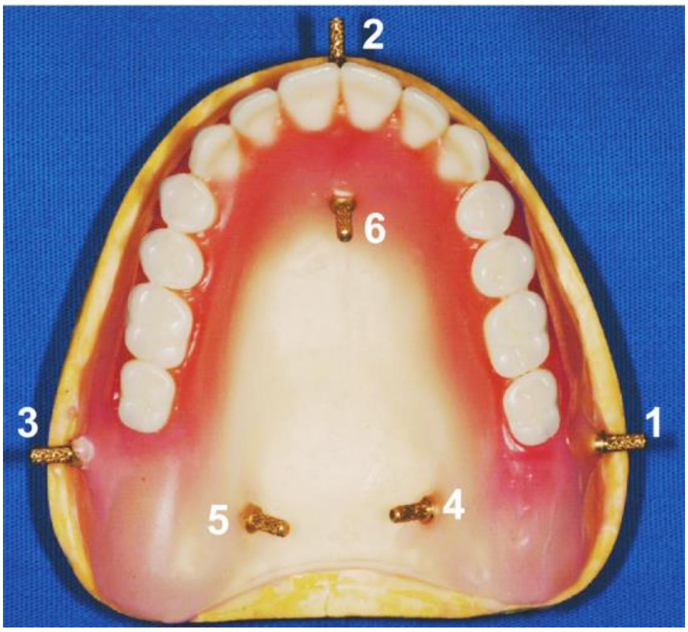

Fig. 2 Denture base with identical arch of teeth, and dowel pins at agreed landmarks

3.3 Measurements

Because 6 dowel pins were positioned around the denture base at different heights this enabled their positions to be recorded in three dimensions. Each pin position was recorded and measured using a Reflex Microscope (Consultantnet Ltd, Cambridge, UK), a modified stereoscopic microscope which allows measurements in three dimensions to an accuracy of 4µm using a virtual point of light. The pins were positioned such that they are all visible in the horizontal plane when viewing the denture base from the vertical when placed on the sliding viewing table (figure 3).

When the virtual light spot is positioned over the pin, the position of the pin is recorded by activating a switch and the software then records x, y, and z coordinates (Speculand, Butcher, Stephens, 1988), where horizontal movement of the sliding table gives x and y coordinates and vertical movement of the microscope gives z coordinates.

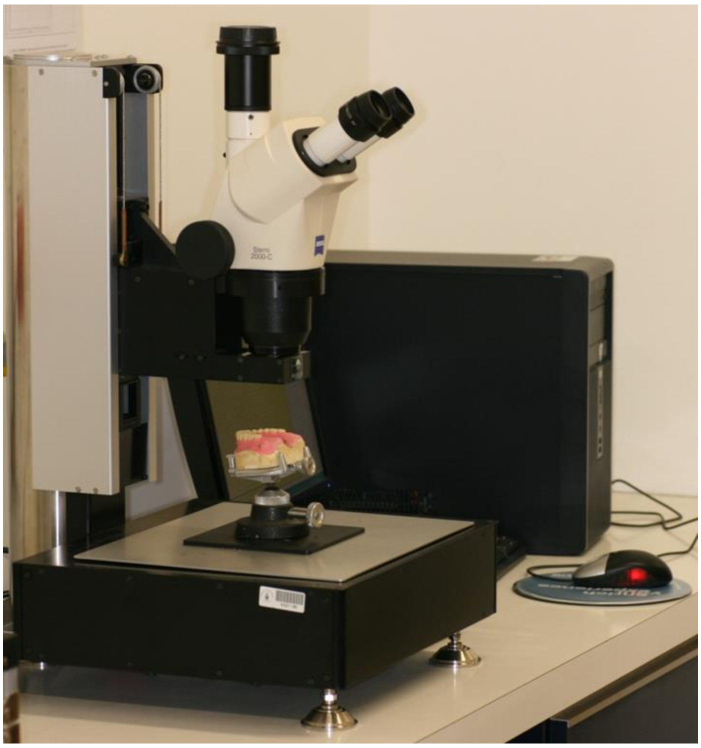

Fig. 3 Reflex Microscope

The Reflex Microscope was reported to produce operator error less than 0.15mm for linear distances, compared with 0.22mm when using the travelling microscope (Bhatia & Harrison, 1987 cited in Speculand et al 1988). The positioning of the object is said to be inconsequential, as the reference point must always be at the focal point of the lens as indicated by the light spot.

After waxing the teeth to the base and before flasking, the position of each pin was measured. Immediately after curing, and deflasking, but before removing the denture base from the model, the pin positions were again recorded. Final measurements were made after removal of the base from its model. The zero function on the microscope was used to reset all coordinates after each reading.

The following measurements were made:

- deltaX 4-5
- deltaX 1-3
- deltaR 4-5
- deltaR 1-3
- theta3D 4-6-5
- theta3D 1-2-3

Where deltaX is the distance between two points projected onto the X plane, and deltaR is a straight line distance in 3 dimensions between the two points. Theta3D is the 3-dimensional angle defined by three points measured at the point where the two lines from the other two points intersect.

3.4 Analyses

For each distortion measure, a one-way analysis of variance (ANOVA) was conducted with method as the factor. Where the data did not meet the assumptions of this test, a non-parametric alternative, the Kruskal-Wallis test, was used. (The results of the Kruskal-Wallis test are reported in any case, as a check on the ANOVA results, given the comparatively low sample size.).

CHAPTER 4: RESULTS

For each dimension measured there were changes in coordinates, which indicated there was dimensional change of the denture base following the second cure for all curing methods. The differences are shown in Table 1. These differences were converted to percentage changes for statistical comparisons.

Data analysis was carried out in SAS. (SAS Institute Inc., (2002-2010) Cary, NC, USA). The 5% significance level was used to test for statistical significance.

Strength of associations was measured using Cohen's d. The following scale of interpretation was used:

0.80 and above	large effect
0.50 to 0.79	moderate effect
0.20 to 0.49	small effect
Below 0.20	near zero effect

Statistical outliers:

Outliers are single observations which are numerically distant from the rest of the data, and when excluded or included will have noticeable influence on the results (Campbell & Machin, 2000). In this study 7 such observations were identified: 3 in method 3, 2 in method 1, and 1 in methods 2 and 4. Some intermediate data were lost in one model in method 4.

Outliers were removed for the ANOVA analyses, as retaining them would render the results of this analysis invalid. Outliers were, however, retained for the non-parametric Kruskal-Wallis test which is designed for such instances where the distribution deviates from normal.

Table 1: Second cure differences in measurement (mm) for each dimension measured

	Dimension measured																	
	Pins 4 - 5: linear			Pins 4 - 5: 3D			Pins 1 - 3: linear			Pins 1 - 3: 3D			Angle 465: 3D			Angle 123: 3D		
	Differences			Differences			Differences			Differences			Differences			Differences		
Method	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model
1	-1.312	-0.149	-1.461	-1.308	-0.16	-1.468	-2.564	2.528	-0.036	-2.595	2.526	-0.069	-0.891	-0.539	-1.43	-2.141	1.107	-1.034
1	-0.38	0.639	0.259	-0.378	0.662	0.284	-0.087	0.035	-0.052	-0.035	0.086	0.051	-0.136	1.523	1.387	0.384	0.339	0.723
1	-0.64	0.088	-0.552	-0.608	0.055	-0.553	0.927	0.738	1.665	1.104	0.55	1.654	-2.231	0.368	-1.863	1.443	0.414	1.857
1	0.258	0.335	0.593	0.298	0.282	0.58	-0.226	1.642	1.416	-4.791	4.791	0	1.11	0.378	1.488	-5.564	5.83	0.266
1	-0.077	0.229	0.152	-0.071	0.263	0.192	0.293	0.007	0.3	0.229	-0.002	0.227	0.548	0.392	0.94	0.014	0.413	0.427
2	-0.826	0.21	-0.616	-0.801	0.184	-0.617	0.385	-0.799	-0.414	0.456	-0.686	-0.23	-6.232	4.426	-1.806	0.945	-2.171	-1.226
2	0.162	0.21	0.372	0.03	0.422	0.452	0.434	-0.329	0.105	0.46	-0.343	0.117	1.087	-0.633	0.454	0.056	0.043	0.099
2	-0.936	-0.065	-1.001	-0.935	-0.065	-1	0.172	0.553	0.725	0.072	0.634	0.706	-5.13	-1.426	-6.556	-0.421	-0.667	-1.088
2	-0.267	0.289	0.022	-0.289	0.29	0.001	-0.48	0.278	-0.202	-0.446	0.296	-0.15	-0.412	0.057	-0.355	0.239	0.083	0.322
2	0.132	0.018	0.15	0.081	0.004	0.085	-0.337	0.465	0.128	-0.369	0.484	0.115	0.751	-0.648	0.103	0.342	0.252	0.594
3	-0.128	-0.482	-0.61	0.359	-2.378	-2.019	-1.909	0.94	-0.969	-1.906	0.931	-0.975	1.515	-0.7	0.815	-1.853	-1.115	-2.968
3	0.109	0.241	0.35	0.529	-0.309	0.22	-0.611	0.52	-0.091	-0.697	0.516	-0.181	0.519	-0.832	-0.313	-0.646	-0.851	-1.497
3	0.71	-2.136	-1.426	1.77	-3.275	-1.505	1.046	-0.961	0.085	1.152	-0.936	0.216	2.663	-6.245	-3.582	1.231	-2.827	-1.596
3	-1.163	-0.173	-1.336	-1.177	-0.155	-1.332	0.63	-0.131	0.499	0.566	-0.104	0.462	-1.158	-0.706	-1.864	1.458	-0.61	0.848
3	-0.573	-0.753	-1.326	-0.571	-0.753	-1.324	1.975	-2.975	-1	1.965	-2.958	-0.993	0.328	-1.846	-1.518	3.684	-3.474	0.21
3	1.005	0.197	1.202	1.01	0.264	1.274	-0.888	0.538	-0.35	-1.007	0.481	-0.526	2.782	0.581	3.363	-0.731	-0.965	-1.696
4	0.44	0.116	0.556	0.425	0.117	0.542	-1.274	0.618	-0.656	-1.271	0.641	-0.63	-0.009	-0.262	-0.271	-0.776	0.219	-0.557
4	-0.906	-0.796	-1.702	-0.908	-0.797	-1.705	-1.313	1.693	0.38	-1.296	1.682	0.386	-1.024	-1.608	-2.632	-1.997	1.186	-0.811
4			-0.835			-1.27			0.725			0.478			8.538			-2.229
4	0.852	-0.258	0.594	0.856	-0.263	0.593	0.649	0.802	1.451	0.62	0.794	1.414	1.358	-0.902	0.456	0.617	-0.107	0.51
4	-0.473	-0.175	-0.648	-0.265	-1.28	-1.545	-0.667	0.487	-0.18	-0.652	0.414	-0.238	-0.781	1.045	0.264	-0.407	0.046	-0.361

From the statistical analyses, and comparing differences within and between methods, only two dimensional changes emerged as showing statistically significant differences as follows:

Linear change (x-axis) between pins 1 and 3: There was a significant difference between methods (ANOVA: Model 24 removed as outlier; p=0.0158) when comparing the absolute change between the waxed base and the deflasked base. Post-hoc tests showed that the distortions for Methods 1 and 2 were lower than for Method 3. The effect sizes were large (Cohen's d=0.93 and 0.99 for Methods 1 and 2, respectively, vs. Method 3). The Least-Squares Means are shown in figure 4.

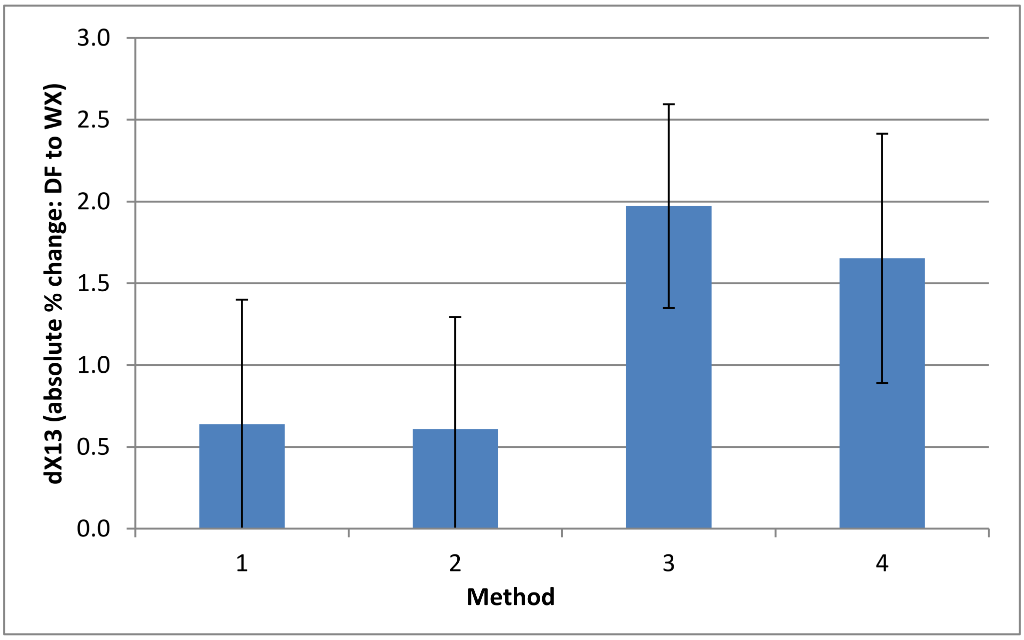

Fig. 4 Least squares means for pins 1 – 3 linear (x-axis) measurement. Absolute percentage change from wax to deflasked base. Error bars denote the 95% confidence interval for the mean. Distortion for Methods 1 and 2 was lower than that for Method 3

Three-dimensional change between pins 4 and 5: ANOVA revealed a significant difference between methods (p=0.039), between the waxed base and the processed, but on-the-cast base. Post-hoc tests showed that the distortion for Method 2 was lower than that for Method 3. The effect size was large (Cohen's d=1.9). The Least-Squares (LS) Means are shown in figure 5.

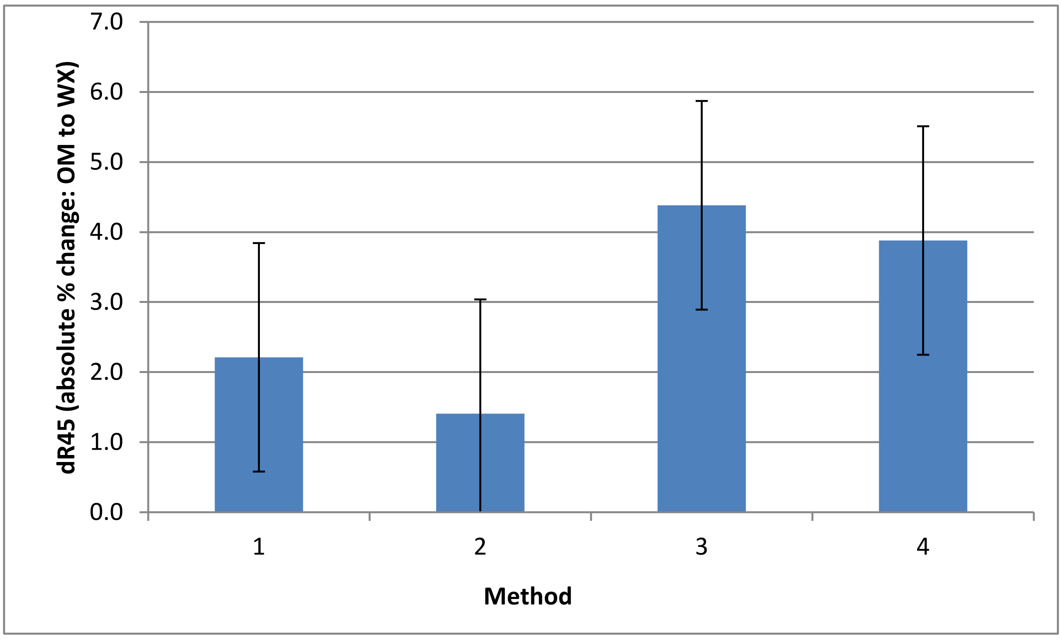

Fig. 5 Least squares means for pins 4 – 5: 3-D measurement. Absolute percentage change from wax to processed but on-cast base. Error bars denote the 95% confidence interval for the mean

Although there were two significant differences, these were too isolated to select the best or worst method overall. The overall change between the waxed up base and the final base removed from the flasked model would be the most significant change from a clinical perspective, so these absolute percentage changes are shown in Table 2. The means for all methods are shown in Table 3.

Table 2: Absolute percentage change.

	Dimension measured																	
	Pins 4 - 5: linear			Pins 4 - 5: 3D			Pins 1 - 3: linear			Pins 1 - 3: 3D			Angle 465: 3D			Angle 123: 3D		
	Absolute % change			Absolute % change			Absolute % change			Absolute % change			Absolute % change			Absolute % change		
Method	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model	Wax to Deflasked	Deflasked to Off Model	Wax to Off Model
1	4.59	0.55	5.11	4.57	0.59	5.13	4.27	4.40	0.06	4.32	4.39	0.11	1.58	0.97	2.53	2.83	1.51	1.37
1	1.41	2.41	0.96	1.40	2.49	1.05	0.14	0.06	0.08	0.06	0.14	0.08	0.25	2.80	2.54	0.51	0.45	0.97
1	2.32	0.33	2.00	2.20	0.20	2.00	1.55	1.22	2.79	1.85	0.90	2.77	4.07	0.70	3.40	1.95	0.55	2.51
1	0.95	1.22	2.18	1.10	1.03	2.13	0.39	2.84	2.44	7.66	8.30	0.00	2.07	0.69	2.77	7.61	8.63	0.36
1	0.30	0.89	0.59	0.27	1.02	0.74	0.47	0.01	0.48	0.37	0.00	0.36	1.02	0.72	1.75	0.02	0.55	0.57
2	2.71	0.71	2.02	2.63	0.62	2.03	0.66	1.36	0.71	0.78	1.17	0.39	10.61	8.43	3.07	1.26	2.86	1.64
2	0.54	0.69	1.23	0.10	1.38	1.48	0.73	0.55	0.18	0.77	0.57	0.20	1.76	1.01	0.74	0.07	0.06	0.13
2	3.01	0.22	3.22	3.01	0.22	3.22	0.29	0.94	1.23	0.12	1.07	1.19	8.16	2.47	10.43	0.56	0.89	1.45
2	0.93	1.02	0.08	1.01	1.02	0.00	0.80	0.46	0.33	0.74	0.49	0.25	0.72	0.10	0.62	0.32	0.11	0.43
2	0.46	0.06	0.53	0.28	0.01	0.30	0.57	0.79	0.22	0.62	0.82	0.19	1.35	1.15	0.18	0.46	0.33	0.79
3	0.44	1.67	2.10	1.18	7.72	6.63	3.19	1.62	1.62	3.18	1.60	1.63	2.50	1.13	1.34	2.45	1.51	3.92
3	0.37	0.81	1.18	1.77	1.02	0.74	1.03	0.88	0.15	1.17	0.88	0.30	0.92	1.46	0.56	0.87	1.15	2.01
3	2.45	7.20	4.92	6.11	10.65	5.20	1.78	1.61	0.14	1.96	1.57	0.37	4.74	10.62	6.38	1.64	3.71	2.13
3	4.03	0.62	4.63	4.07	0.56	4.61	1.06	0.22	0.84	0.96	0.17	0.78	2.01	1.25	3.24	2.01	0.82	1.17
3	1.94	2.61	4.50	1.94	2.61	4.49	3.27	4.78	1.66	3.26	4.75	1.65	0.56	3.16	2.61	4.99	4.48	0.28
3	3.65	0.69	4.37	3.67	0.93	4.63	1.50	0.92	0.59	1.69	0.82	0.89	5.08	1.01	6.15	0.99	1.32	2.30
4	1.59	0.41	2.01	1.53	0.42	1.96	2.17	1.07	1.12	2.16	1.11	1.07	0.02	0.46	0.47	1.05	0.30	0.76
4	3.12	2.83	5.86	3.12	2.83	5.86	2.23	2.95	0.65	2.21	2.93	0.66	1.75	2.79	4.49	2.69	1.64	1.09
4	0.00	0.00	2.90	0.00	0.00	4.34	0.00	0.00	1.26	0.00	0.00	0.83	0.00	0.00	15.47	0.00	0.00	3.02
4	2.98	0.88	2.08	2.99	0.89	2.07	1.09	1.33	2.44	1.04	1.32	2.37	2.38	1.55	0.80	0.83	0.14	0.69
4	1.63	0.61	2.24	0.89	4.32	5.17	1.12	0.82	0.30	1.09	0.70	0.40	1.35	1.82	0.45	0.54	0.06	0.48

Table 3 Mean absolute percentage changes.

	Dimension measured																	
	Pins 4 - 5: linear			Pins 4 - 5: 3D			Pins 1 - 3: linear			Pins 1 - 3: 3D			Angle 465: 3D			Angle 123: 3D		
	Absolute % change			Absolute % change			Absolute % change			Absolute % change			Absolute % change			Absolute % change		
Method	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**	**Wax to Deflasked**	**Deflasked to Off Model**	**Wax to Off Model**
1	1.91	1.08	2.17	1.91	1.06	2.21	1.36	1.71	1.17	2.85	2.75	0.67	1.80	1.18	2.60	2.58	2.34	1.16
2	1.53	0.54	1.42	1.41	0.65	1.41	0.61	0.82	0.53	0.61	0.82	0.45	4.52	2.63	3.01	0.53	0.85	0.89
3	2.15	2.27	3.62	3.12	3.91	4.38	1.97	1.67	0.83	2.04	1.63	0.93	2.64	3.10	3.38	2.16	2.17	1.97
4	1.86	0.95	3.02	1.71	1.69	3.88	1.32	1.24	1.15	1.30	1.21	1.07	1.10	1.32	4.34	1.02	0.43	1.21

The maximum values for the changes seen from the waxed denture base to the cured base after deflasking and removal from the model are shown in Table 4, and represented graphically in Figure 6.

Table 4 Maximum mean percentage changes for the differences between the waxed base and after the second cure, when removed from the model after deflasking.

Dimension measured					
Pins 4 - 5: linear	**Pins 4 - 5: 3D**	**Pins 1 - 3: linear**	**Pins 1 - 3: 3D**	**Angle 465: 3D**	**Angle 123: 3D**
3.62	4.38	1.17	1.07	4.34	1.97

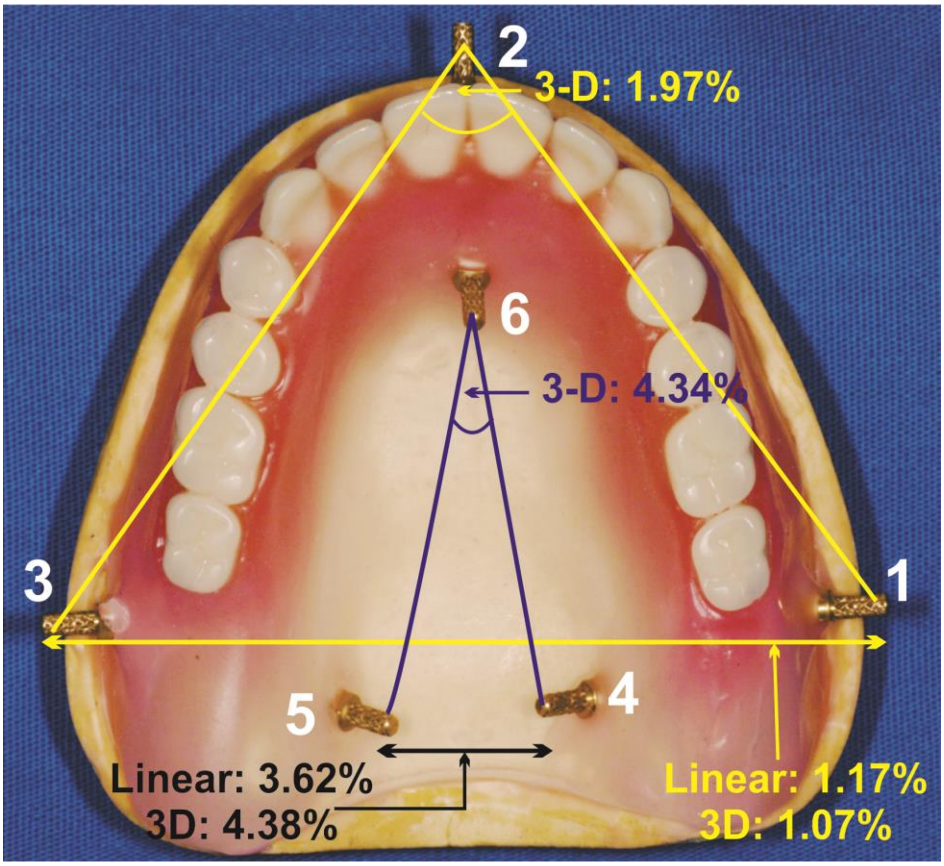

Fig. 6 Graphical representation of the maximum mean percentage changes for the differences between the waxed base and after the second cure, when removed from the model after deflasking.

Table 5 shows the actual maximum mean values in mms (for the between pin measurements) and degrees (for the 3-D angle measurements) calculated from the mean values of the method showing the worst percentage change.

Table 5. Maximum mean percentage values converted to lengths and degrees

Dimension measured					
Pins 4 - 5: linear: mm	**Pins 4 - 5: 3D: mm**	**Pins 1 - 3: linear: mm**	**Pins 1 - 3: 3D: mm**	**Angle 465: 3D: degrees**	**Angle 123: 3D degrees**
0.99	1.28	0.71	0.63	2.48	1.46

CHAPTER 5: DISCUSSION

The methods used in this study are well established. Kern (1941) cited in Polyzois et al (1987) identified those measurements which influence the fit of the denture significantly. These measurements were from flange-to-flange, molar-to-molar, and the depth of the palate. Yeung et al (1995) made reference points in the incisive papilla, tuberosities and mid-posterior palatal border, at the central incisors and second molar regions, in their study to determine linear dimensional changes of denture bases when using the double cure technique under different temperatures.

When evaluating different denture processing techniques one of the factors which determines the soundness of such techniques is the dimensional stability and adaptation of denture bases to the casts. In this study three aspects of denture base distortion were assessed, the linear posterior change, 3-D posterior change, and overall 3-D distortion as represented by angular measurements.

Statistical analysis revealed the existence of discordant data as outliers. The most likely explanation for these is that they are the result of laboratory processing inconsistencies. Although a strict processing protocol was used, and one dental technician carried out the processing procedures, the technician was instructed to use his normal techniques. Hence aspects such as polymer/monomer ratios for the resin may not have been strictly controlled. But this is the reality of modern dental laboratories, when several denture bases are processed at the same time. Despite these outliers, the non-parametric tests showed that there were no statistically significant differences between methods or stages within the processing method, except for two instances.

An intermediate stage measurement, that of the deflasked base whilst still on its model, was introduced in this study to see if there were any significant changes as a result of stress release when finally removing the base from its flasked model. There clearly were some changes, but these were not significant, and so the main change of interest is that from the base with waxed teeth, to the final, off the model dual-cured base.

Method 3 displayed the most amount of distortion in the posterior aspect of the denture, and statistically this method displayed the most number of outliers. The two factors (distortion and outliers) may indeed be associated in this study. This method has been the one most commonly accepted as conventional wisdom for reducing dual-cure distortions, but such wisdom has been derived from studies using the older generations of resins. The need for speed in processing has led manufacturers to produce resins that are now labelled specifically as ‘rapid cure’, and thus these formulations may not be appropriate for long cures at lower temperatures.

The linear distortions for methods 1 and 2 were lower than those for method 3. It is possible that this may be due to the release of internal stresses within the base during the second cure. These stresses can influence denture base dimensional stability if (a) the temperature for the second cure reaches the glass transition temperature of the denture base so that it undergoes changes in its physical properties; or (b) stresses are released when the base is removed from the cast (Turck et al, 1992). The full data shown in Table 1 illustrate this phenomenon where in general (for all methods except method 3), the measurements from waxed to deflasked (but still on cast) show a contraction which is denoted by the negative values. For method 3 the contraction was evidenced in the second and third measurements, which depict the amount of internal stress released or created during processing. This observation was also made by Al-Hanbali et al (1991), and they reported that denture bases moved in different amounts and directions during the second cure.

The base acrylic in method 1 was exposed to boiling water for 20 minutes. Although the temperature is higher than the recommended 72°C, the time of exposure is reduced to 20 minutes. Reducing exposure time for the second cure may interrupt the internal temperature rise which, uncontrolled, may reach or exceed the glass transition temperature of the material resulting in physical changes to the material.

Another factor is the temperature at which water boils. At sea level the boiling point of water is 100°C but water boils at lower temperatures at higher altitudes. At an altitude of 1753m water boils at a temperature of 94°C and this could be an added advantage to method 1. Yeung et al (1995) stated that as long as there is quick heat dissipation a higher temperature can be used in order to increase the efficiency of the polymerisation of the resin. The cooling methods used in methods 1 and 4 served to dissipate the internal heat by exposing the flask to a source of reduced temperature (cold water).

This cooling technique may aggravate the differential rates of contraction of the resin and the cast, thus increasing the internal stresses. This may be true if the transitional glass temperature was exceeded during the heating process, and when that occurs it is inconsequential which cooling technique is used. Yeung et al (1995) investigated the effect the rate of cooling may have on linear dimensional changes associated with dual cure methods. They reported overall linear dimensional changes of -0.44% and -0.51% for the slow cooling and rapid cooling methods; there was no statistical significance. This serves to further explain the results in this study, for methods 1 and 4 where rapid cooling techniques were used.

The denture bearing area is not a rigid base onto which the denture is mechanically fixed, but is a visco-elastic tissue to which it adheres. Furthermore the denture base is not imposed directly onto the oral mucosa; there is a film of intervening saliva which is said to enhance denture retention (Edgerton et al, 1987), by the action of surface tension achieved from the formation of a saliva meniscus along the denture periphery. This peripheral seal needs to extend to the posterior border of the denture. The posterior palatal seal aims to maintain denture retention during function by maintaining contact between the denture base and the palatal tissues, and compensates for processing changes (Jacobson, 1983). Although this factor is not always applicable to denture processing, patients with steep palatal vaults may experience this discrepancy between the palate and the posterior aspect of the denture base.

The mean percentage changes measured in this study must be translated into real changes in distances or angles, in order to ascertain the clinical relevance of these changes, for if they are too great, the distortion of the denture base will exceed the adaptive capacity of the mucosa as well as disrupt the peripheral seal, and the denture base will not be retentive. Table 5 shows these real amounts, and it can be seen from these figures that they are most unlikely to affect the fit of the denture or disrupt the peripheral seal. The largest mean change is seen in the three-dimension distance between pins 4 and 5, the innermost pins in the posterior palate, but this was only 1.3mm. This also showed the worst change of all measurements, but this was still only 2.0mm.

For occasions where time is important, such as in the supply of dentures to rural underserved communities, the rapid cure methods used here are unlikely to cause clinically relevant changes.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Although the literature has conventionally recommended long second cures at low temperatures, the improvements in the material properties of denture base resins may make this recommendation obsolete. The ability to manipulate the modern ‘rapid cure’ heat activated PMMA resins at various temperatures and achieve stable results questions the need for the long processing technique. The results in this study are in accord with this, as the temperature and the time were varied considerably, but the measured distortion including 3D distortion did not yield any statistically significant changes. When compared with those methods used frequently in commercial laboratories, the method recommended in the literature did not display immunity to warpage but instead may be more vulnerable due to the prolonged exposure to heat. Although a limitation of this study was that only one brand of denture base resin was tested, it is likely to be representative of the modern resins. Other materials should be tested, though, so that the results can be compared.

The concept of appropriatech and simplified techniques such as the CD4 denture fabricating technique will benefit from these results as the rapid cure methods such as in method 1 will be unlikely to produce distortions that would have any adverse clinical outcomes.

REFERENCES

Academy of Prosthodontics of South Africa 2012. http://wwwacademyofprosthodontics.co.za Accessed December 2012

Al-Hanbali E, Kelleway JP, Howlett JA. Acrylic distortion following double processing with microwaves or heat. J Dent 1991; 19:176-180

Bartoloni JA, Murchison DF, Wofford DT ,Sarkar NK . Degree of conversion in denture base materials for varied polymerisation techniques. J Oral Rehab 2000; 27:488-493

Brewer AA. Prosthodontic research in progress at the school of aerospace medicine. J Prosthet Dent 1963; 13(1):49-69

Campbell MJ, Machin D. Statistical inferences. In: Campbell, Machin (Eds).Medical statistics a common-sense approach 3rd Ed. Wiley New York, 2000:77-92

Carlsson GE, Omar R. The future of complete dentures in oral rehabilitation. A critical review. J Oral Rehab 2010; 37:143-156

Chen JC, Lacefield WR, Castleberry DJ. The effect of denture thickness and curing cycle on the dimensional stability of acrylic resin denture bases. Dent Mater 1988; 4:20-24

Darvell BW. Acrylics. In: BW Darvell, editor. Materials Science for Dentistry 9th Ed. Woodhead publishing, United Kingdom, 2009; 108-127

Edgerton M, Tabak LA, Levine MJ. Saliva: a significant factor in removable prosthodontic treatment. J Prosthet Dent. 1987; 57:57-66.

Graser GN. Completed bases for removable dentures. J Prosthet Dent 1978; 39(2):232-236

Harrison A, Huggett R, Zissis A, Vowels RW. A comparison of the dimensional accuracy of microwave and conventionally polymerized denture base material. Clin Mater 1993; 14:133-137

Jacob RF. The traditional therapeutic paradigm: Complete denture therapy. J Prosthet Dent 1998; 79:6-13

Jacobson TE, Krol AJ. A contemporary review of the factors involved in complete denture retention, stability, and support. Part I: retention. J Prosthet Dent 1983;49:5-16

Langer A. the validity of maxillomandibular records made with trial and processed bases. J Prosthet Dent 1981; 45(3):253-258

Lechner SK, Lautenschlager EP. Processing changes in maxillary complete dentures. J Prosthet Dent 1984; 52(1):20-24

Owen CP. Appropriatech: Prosthodontics for the many, not just for the few. Int J Prosthodont 2004; 17:261-262

Owen CP. Guidelines for a minimum acceptable protocol for the construction of complete dentures. Int J Prosthodont 2006;19:467-74

Owen CP, MacEntee M. The impact of socioeconomic, cultural, and technological changes and notion of standards of care and alternative protocols. In: Zarb G, Hobkirk JA, Eckert SE, Jacob RF (Eds) Prosthodontic treatment for the edentulous patients. 13th Ed. Elsevier Mosby, St Louis, 2012:409-420

Phoenix RD. Denture base resins. In: Anusavice, editor. 11th Ed. Phillips' Science of Dental Materials. Saunders St Louis, Missouri 2003: 721-757

Polukoshko KM, Brudvik JS, Nicholls JI, Smith DE. Evaluation of heat cured resin bases following the addition of denture teeth using a second heat cure. J Prosthet Dent 1992; 67:556-62

Polyzois GL, Karkazis HC, Zissis AJ, Demetriou PP. Dimensional stability of dentures processed in boilable acrylic resins: a comparative study. J Prosthet Dent 1987; 57:639-647

Speculand B, Butcher GW, Stephens CD. Three-Dimensional measurement: The accuracy and precision of the reflex microscope. Br J Oral Maxillofac Surg 1988; 26:276-283

Turck MD, Lang BR, Wilcox DE, Meiers JC. Direct measurement of dimensional accuracy with three denture processing techniques. Int J Prosthodont 1992;5:367-372

Yeung KC, Chow TW, Clark RFK. Temperature and dimensional changes in the two-stage processing technique for complete dentures. J Dent 1995;23:245-253

Papers cited but not read

Bhatia SN, Harrison VE. Operational performance of the Travelling Microscope in the measurement of dental casts. J of Orthod 1987;14:147-153

Craig RG. Plastics (prosthetic applications). In: Restorative Dental Materials. 6th edition London, 1980 C.V. Mosby chap 14

Kimura H, Teraoka F, Saito T. Applications of microwave for dental technique. Adaptability of cured acrylic resins. J Osaka Univ. Dent. Sch. 24:21-29

Kern WR. Possible dimensional changes in denture base materials. J Am Dent Assoc 1941;28:451-60