CHAPTER 4

DISCUSSION AND CONCLUSION

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4.1 Method of specimen preparation and 3-point flexural bending test.

A polymerization cycle using heat at 70°C for 7 hr followed by 1 hour at 100°C in a water bath unit allows maximal conversion of residual monomer and at the same time the denture has less porosity irrespective of thickness of the denture base (Harrison & Huggett,1992). The residual monomer levels of denture base polymers polymerized by using this cycle ranged from 0.54 to 1.08% (Harrison & Huggett, 1992). This level of residual monomer normally is well tolerated by most patient. However for some patients who are genuinely allergic to residual monomer an alternative material may need to be used for denture base construction.

A 3-point flexural bending test was conducted on the Instron universal testing machine. Based on the formula for flexural strength, flexural properties vary with specimen depth, support span, length, temperature, atmospheric conditions, and rate of straining. The testing procedures were carefully standardized. For this study, the ISO specifications, 1567:1999 for denture base materials were used in specimen preparation and testing procedures. However, the time of storage of specimens was longer compared with the specification. In this study, specimens were immersed for 30 days to allow water saturation (Stafford & Smith, 1968). It was reported by Vallittu (2000) that most of denture base polymers became saturated within 4 weeks of storage in water. By this time, the amount of water molecules within the polymer has reached equilibrium. The effect of water sorption was a reduction in mechanical properties of the denture base polymers (Takahashi, 1999 and Vallittu, 2000). Therefore, in this study as suggested by Vallittu (2000), all specimens were immersed for one month to allow complete water saturation before testing to provide more clinically relevant flexural values. Water acts as a plastisizer to reduce the mechanical properties of the polymer (Takahashi, 1999). At the same time, as the denture polymer is immersed in water, soluble constituents such as unreacted monomers, plasticizers, and inititors leach out and the microvoids that are formed will be filled with water molecules by inward diffusion (Vallittu, 1995).

4.2 Material

The material most commonly used for the fabrication of dentures is PMMA. Although it is esthetic, PMMA is still far from ideal in fulfilling the mechanical requirements of a prosthesis. There have been ongoing efforts to improve the physical and mechanical properties of PMMA. The reinforcement of resin with carbon can improve the flexural modulus of acrylic resin (Ruyter et al., 1986). However, carbon reinforcement has the disadvantage of altering the aesthetic qualities because of its colour and toxicity (Yazdanie and Mahood, 1985). Rubber reinforced resin was shown to absorb greater amounts of energy at a higher strain rate before fracture compared with standard resins (Rodford, 1986). However, while the impact strength is often improved, the resin maybe too flexible. Reinforcement with metal strengthener has been reported to cause stress concentrations around the embedded metal and the net effect can actually weaken the polymer (Ruffino,1985). This problem is often the result of poor adhesion between the acrylic resin matrix and the fibre metal. One of the problems with polyaramid fiber is the extension of fibres that resulted in a rough denture surface that may produce mucosal irritation and discomfort for the patient (Foo et al., 2001).

A relatively new visible light-polymerized denture base resin (Eclipse, Denstply international Inc) was introduced to the dental market as an alternative to heat-polymerized and chemically-polymerized denture base resins. One of the advantages of light-polymerized denture base resin, as advocated by the manufacturer, is ease of manupulation. Proportioning and mixing are not required, so there will be no problem with incorrect powder:liquid ratios as can occur with PMMA acrylic resin. Light-polymerizing material can be adapted easily to the working cast without the neccesity of flasking as in the conventional method of processing acrylic resin dentures, reducing the laboratory time. Grossman and Savion (2005) described the method of construction of a definitive obturator prosthesis using Eclipse denture base polymer and claimed that the laboratory time and costs were reduced. The first 2-mm thickness of the material was polymerized by using hand-held polymerizing light to polymerize deep areas inside the defect. It was then followed by irradiating the prosthesis in the processing unit for 10 minutes. Further additional layers were polymerized incrementally to facilitate improved light penetration, complete polymerization and improve the overall strength of the final prosthesis. The use of the material also facilitated jaw relation records because there was more retention and stability obtained from the permanent record base.

Air barrier coating, which is necessary for the light-polymerizing system, provides a barrier between the surface of the material and atmospheric oxygen during polymerization. As advocated by the manufacture, this barrier allows additional polymerization of the resin's outer surface. When oxygen is present, surface layer polymerization of resin (monomer conversion) is inhibited (Barron et al., 1993). Surface inhibition will lead to underpolymerized resin surface that may become irregular and unstable in colour, with a tendency for bacterial and fungal adherence (Segal et al., 1988). Therefore, it is important to use air barrier coating prior to polymerization.

A laboratory study has reported that the light-polymerized urethane-based polymer could produce a toxic effect on oral epithelial cells (Lefebvre et al., 1991). It was thought that the extent of the toxicity was related to the specific formulation of the material and not to the degree of polymerization. The air barrier coating was shown to increase toxicity when the epithelial cells were exposed to it (Lefebvre et al., 1991 and Barron et al., 1993). The investigators also found that air barrier coating on Triad specimens significantly inhibited protein synthesis in oral epithelial cells as compared with those without the coating. The investigators suggested that, further investigation was needed to evaluate the material's biocompatibility and toxicity.

4.3 Surface hardness

Microhardness is defined as the resistance to permanent surface indentation or penetration. Denture base material should have sufficient surface hardness to prevent excessive wear of the material by abrasive denture cleansers or food. Normally, cross-linking agents are added to denture base materials to improve their surface hardness.

The pilot study showed that when the specimens were irradiated for 10 minutes or less there was a significant difference in the surface hardness between the surface exposed to the light and the fitting surface underneath. With light polymerization, polymerization starts from the irradiated surface, creating a difference in hardness between the irradiated surface and non-irradiated surface. Maximal intensity of the light radiation beam is concentrated near the surface of a light-polymerized composite resin (Craig & Powers, 1997). Therefore, the top surface recorded higher hardness values compared with the bottom surface. As the light penetrated the material, it was scaterred and reflected and lost some of its intensity. As in any composite resin, the filler content and particle size influenced the degree of polymerization at a given depth from the surface (Craig & Powers, 1997). Microfilled composites with smaller and more numerous particles have been reported to scatter more light, and longer exposure times are required to obtain adequate depth of polymerization of the composite. In this study, the size of the filler particles is unknown because this fact was not revealed by the manufacturer. However, in this study, 10 minutes irradiation by using high intensity visible light of 400-500 nm wavelength resulted in maximal and uniform surface hardness values for both irradiated and non-irradiated surfaces. This result indicates that 10 minutes irradiation time provided complete polymerization throughout the 3-mm thickness of the material, and conformed with the manufacturer's recommended curing time of 10 minutes when using Eclipse material to process dentures.

A comparison of surface hardness between the three types of denture base resins demonstrated that Eclipse resin had the highest surface hardness value. It was also found that heat-polymerized PMMA (Meliodent) and chemically-polymerized PMMA (Probase Cold) exhibited significantly different surface hardness even though they are similar chemically except for the chemical activator present in the later. It was expected that chemically-polymerized PMMA would have inferior mechanical properties because of the lesser degree of polymerization as compared with heat-polymerized PMMA. This finding was in agreement with another study done by Stafford and Huggett, (1978).

Eclipse material is different from the other two denture base polymers in the composition and mode of polymerization. It is a urethane dimethacrylate-based denture polymer and contains microfine silica fillers, which are thought to enhance mechanical properties of the material, including its surface hardness. Therefore, it is not surprising to find it harder than the other two PMMA-based polymers. This study was an agreement with the studies by Khan et al., (1987) and Al Mulla et al., (1988) where they found that Triad material, which was also a light-polymerized urethane dimethacrylate polymer, exhibited increased surface hardness when compared with PMMA. However, the method that was used to measure the surface hardness was not the same method used in this study. Therefore direct comparison of the actual surface hardness values between Eclipse and Triad materials cannot be made. A comparison of the hardness between filled resin and unfilled PMMA in another study (Heath and Wilson, 1977) indicated that the former was superior. Materials with higher surface hardness could withstand the abrasion of a tooth brush and a dentifrice better than the unfilled PMMA polymer.

Flexural strength and flexural modulus

Strength can be referred to as the ability of the prosthesis to resist applied forces (load) without fracture or excessive deformation (McCabe, 1998). It is probably one of the more important properties of denture base materials. The oral environment includes cyclic loads during mastication, and the denture wearer may experience millions of cycles of loading and unloading. A denture material with relatively low flexural strength is more likely to fail as a result of cyclic loads, even though the stresses developed by such loads may be well below the strength values of the material (Virendra,2004).

In this study, the flexural strength of Eclipse material was 103 MPa which was higher than the strength of both heat-polymerized and chemically-polymerized PMMA ($P = 4.46 \times 10^{-16}$). The value was comparable to that obtained by Sun et al., (2003). It is assumed that the presence of microfine sillica as an inorganic filler in the Eclipse formulation improved its flexural strength. As in the previous study (Sun et al., 2000)

Eclipse material was shown to have higher flexural strength compared with Triad material.

Flexural modulus was defined as the relative stiffness or rigidity of denture base material. High flexural modulus is one of the requirements of denture base material, so that greater rigidity can be achieved, even in comparatively thin section. In this study, the flexural modulus of Eclipse material was 2498 MPa, which was higher than the value recorded for both heat and chemically-polymerized PMMA-based denture polymers ($P < 0.0001$). The flexural modulus value obtained in this study was also comparable with the value obtained in a previous study (Sun et al., 2003). Therefore, the results of this study confirmed the manufacturer's claim that the flexural properties of light-polymerized urethane dimethacrylate resin are superior to PMMA acrylic resins. However, Al-Mulla et al. (1988) reported that an earlier product of light-polymerized polyurethane based polymer which was known as Triad (Dentsply,USA), had lower flexural strength and flexural modulus compared with heat-polymerized PMMA and chemically-polymerized PMMA.

A comparison of the two PMMA-based polymers showed that chemically-polymerized PMMA recorded lower flexural strength and modulus compared with the heat-polymerized PMMA. It has been reported by Vallittu et al. (1998) that there was always more residual monomer present in chemically-polymerized PMMA. Higher levels of residual monomer present in Probase resin, which is a chemically-polymerized PMMA, may explain this result. The residual monomer acts as a plasticizer which effectively reduces interchain forces so that deformation can occur more easily under load, hence lowering the surface hardness and flexural properties of the polymer (Phoenix et al., 2004 and Jagger 1978). At the same time, the rise in temperature of heat-polymerized PMMA causes mobility of the molecular chains, thereby facilitating the conversion of monomer into polymer which resulted in higher mechanical properties (Al-Mulla, 1988 and Jorge et al., 2003). In addition, the degree of polymerization activated by a chemical activator is not as high as that initiated by heat (Phillips, 1991). Therefore, it is not surprising that the chemically-polymerized PMMA, (Probase Cold) had lower flexural strength and rigidity when compared with heat-polymerized PMMA, (Meliodent).

The results of this study indicate that the light-polymerized urethane dimethacrylate exhibits better mechanical properties than the PMMA-based denture base polymers. Since it has a different chemical composition from PMMA and it does not contains methyl methacrylate monomers, it may be an alternative material for patients who are allergic to PMMA.

4.4 Recommendation for further study

Further studies are required to investigate the biocompatibility of Eclipse material since air barrier coating was shown to increase toxicity if epithelial cells are exposed to these materials (Lefebvre et al., 1991 and Barron et al., 1993).

4.5 Clinical implications

The results of this study indicate that Elipse material exhibited significantly higher surface hardness, flexural strength and flexural modulus compared with PMMA-based denture base polymer. Clinically, denture base polymers should have sufficient surface hardness to prevent excessive wear of material by abrasive denture cleansers or food. Denture base materials with high flexural strength would be able to resist denture base fracture better. A high value of flexural modulus is also required to ensure that stresses encountered during mastication do not cause permanent deformation (McCabe, 1998). Based on the results of this study, Eclipse material could be considered as an acceptable material to function as a denture base polymer.

4.6 Limitation of study

There are a few limiting factors which need to be considered in this study:

1. Although the test procedure used in this in-vitro study simulate the condition in the mouth, the specimens were prepared in a bar shape which was different from the actual denture configuration. A laboratory study with denture base shape should be conducted for the mechanical properties.
2. A fatigue test would be more relevant clinically because it uses low-value repeated forces which more closely simulate the clinical failure mechanism.

4.7 Conclusions

Under the conditions of the present study, the following conclusions were made:

- There was a significant difference in surface hardness between the irradiated and non-irradiated surfaces when polymerized for 4 min ($p = 3.93 \times 10^{-5}$), 6 min ($p = 1.54 \times 10^{-5}$) and 8 min ($p = 0.0174$).
- There was no significant difference in surface hardness between irradiated and non-irradiated surfaces when polymerized for 10 min ($p=0.4219$), 12 min ($p = 0.7921$) and 14 min ($p = 0.3320$).
- Urethane dimethacrylate denture base polymer recorded a significantly higher value for surface hardness compared with heat- and chemically-polymerized denture base polymers ($p = 6.23 \times 10^{-21}$).

- Urethane dimethacrylate denture base polymer recorded a statistically significance higher flexural strength and modulus than both heat and chemical-polymerized denture base polymers ($p = 4.46 \times 10^{-6}$).
- A comparison between the two PMMA denture base polymers indicated that heat-polymerized denture base polymer recorded statistically higher flexural strength, flexural modulus and hardness values when compared with chemically-polymerized denture base polymer ($p = 4.43 \times 10^{-14}$).