6.1 Conclusions

This study was carried out to synthesize an experimental urethane acrylate macromer (UAM) using a palm oil-based polyol and to investigate its application possibilities as a resin for flowable composites. The following conclusions can be drawn from this study:

1. A urethane acrylate macromer was synthesized, and the structure of the urethane groups and acrylate groups were confirmed by FT-IR spectroscopy.
2. The viscosity of the UAM is much lower than Bis-GMA. The lower viscosity has made UAM easier to process than BIS-GMA.
3. Under similar conditions, the percentage of degree of conversion (%DC) of experimental UAM was significantly higher than that of the Bis-GMA. This indicates the potential usefulness of UAM for resin formulation with better mechanical property and biocompatibility enhancement.
4. The percentage of volumetric polymerization shrinkage (%VPS) of the UAM was significantly higher than that of the Bis-GMA.
5. The water sorption and solubility of the UAM was significantly higher than that of the Bis-GMA, presumably due to the hydrophilic nature of its chemical structure.
6. The flexural strength and toughness of the UAM was significantly higher than that of the Bis-GM, since UAM has a flexible urethane linkage and a soft segment of polyol linked with a hard segment phenol of diisocynate. However, the modulus of elasticity of the UAM was lower than the Bis-GMA significantly, because of the strong intermolecular hydrogen bond between the hydroxyl groups of the Bis-GMA.

7. The viscosity of experimental resin systems U/E(3/1), U/E(1/1) and U/E/BT was significantly lower than that of the resin system Bis-GMA/TEGDMA (control). However, the viscosity of the U/BT experimental resin system was significantly higher than that of the Bis-GMA/TEGDMA (control).
8. The %DC and the cross-linking density of experimental resin systems U/BT and U/E(1/1) was significantly higher than that of the Bis-GMA/TEGDMA (control).
9. The %VPS of the experimental UAM-based resin system was comparable to the Bis-GMA/TEGDMA-based resin system (BT), except that the U/BT was significantly higher than BT (control).
10. The water sorption of experimental resin systems U/BT was significantly higher than the BT (control). However, U/E(1/1) and U/E/BT showed significantly lower water sorption and water solubility than that of all experimental resin systems.
11. The flexural strength and toughness of UAM-based resin systems were significantly higher than the Bis-GMA/TEGDMA-based resin system (BT), which may be due to the introduction of flexibility and tougher experimental UAM into the resin systems. The modulus of elasticity of the UAM-based resin systems was comparable to the Bis-GMA/TEGDMA-based resin system (BT), with no significant difference, except that the U/E/BT was higher.
12. The %VPS of the experimental FC-U/E/BT was significantly higher than that of the experimental Bis-GMA/TEGDMA-based flowable composite (experimental control) and commercial Esthet.X flow flowable composite (commercial control), however, FC-U/E was higher than the experimental control only. The

experimental FC-U/BT showed lower %VPS than commercial control Esthet.X flow.

13. The volumetric change of all experimental flowable composites was significantly higher than Esthet.X flow (commercial control). The experimental flowable composite FC-U/BT showed a significantly higher volumetric change than other experimental flowable composites.
14. All the flowable composites have fulfilled the requirement of ISO 4049:2000 for water sorption and solubility. The FC-BT (experimental control) water sorption was significantly lower than FC-U/BT and higher than FC-U/E and the FC-U/E/BT experimental flowable composites. However, the water sorption of each experimental flowable composite was significantly higher than the commercial Esthet.X flow flowable composite (commercial control). The water solubility of the experimental FC-U/BT was significantly higher than the FC-BT (experimental control) and the Esthet.X flow flowable composite (commercial control). The water solubility of the experimental FC-U/E was however significantly lower than both control flowable composites.
15. The flexural strength values of all flowable composites satisfied the requirement of ISO 4049:2000.The flexural strength and toughness of all experimental flowable composites was significantly higher than Esthet.X flow (commercial control).The experimental FC-U/E showed a significantly higher toughness than the experimental FC-U/E/BT. However, the experimental FC-U/E showed a significantly lower modulus of elasticity than the experimental FC-BT (experimental control) and the UAM/(Bis-GMA/TEGDMA) flowable composite. Both flowable composite FC-BT and Esthet.X flow have the same resin (Bis-GMA/TEGDMA), however, the FC-BT showed a higher modulus of elasticity than Esthet.X flow. The mechanical properties of the composite

depend mainly on the filler and interfacial component, and further studies are required in this area.

16. There is no adverse cytotoxicity effect of the UAM-based flowable, based on percentage cell viability determination when compared to FC-BT or Esthet.X flow. There was no significant difference in percentage of viable cells amongst the UAM-flowable composites

6.2 Suggestions for future studies

Based on the findings and limitations of this study, the following are suggestions for further work:

1. Refinement of the polyol to overcome its yellowish colour as this is considered to be a limiting factor for aesthetics.
2. Optimization of the experimental resin UAM as a resin system by varying the filler particles types, sizes and loading to produce new experimental composites. Further physical and mechanical characterization of these new experimental composites must also be carried out.
3. Characterization of physical and mechanical properties of these new experimental composites as compared to Bis-GMA/and or UDMA and oxirane-based composites. The properties to be evaluated include: flexural strength, modulus of elasticity, fracture toughness after ageing and thermal cycling, wear resistance and fatigue resistance. The fracture surfaces will be examined using SEM. Thermal properties including coefficient of thermal expansion and Tg will also be evaluated.
4. Biocompatibility of the UAM will be further assessed using relevant cells to determine membrane integrity, alteration of cell morphology, and determination of cell growth inhibition. The detection of elution compounds from composite materials is also highly recommended using HPLC.
5. Evaluation of new experimental composites as restorative material in animals.
6. Investigating the potential of UAM as a dentine bonding agent.