

CHAPTER 1

INTRODUCTION

1.1 Introduction

Edentulism refers to the condition of being toothless or the lack of natural teeth, whereas a complete edentulous individual is someone who has lost all of their teeth. It has come to emerge as a global phenomenon and affects many individuals, particularly the elder population (Joana et al., 2007). This chronic and debilitating oral health condition can have a significant impact on a person's ability to chew, speak, and maintain proper nutrition. Fortunately, dentures provide a viable and effective solution for rehabilitating the oral health of individuals with edentulism (Meirowitz et al., 2021). Dentures are customised dental prosthetic devices designed for each edentulous individual to replace missing teeth. They can be either partial or complete, depending on the number of teeth needing replacement. Partial dentures are used when some natural teeth remain, while complete dentures are utilised when the patient has lost all their natural teeth. The denture fabrication process is time-consuming and requires extensive human labour since all the dentures are meticulously custom-made to fit the unique oral contour of a specific patient.

Acrylic resin and copolymers are the main materials used to fabricate dentures. Polymethyl Methacrylate (PMMA) is the most common and widely used material throughout the 20th century for fabricating dentures owing to their affordability, ease of fabrication, and aesthetic appearance (Soygun et al., 2013; E. Kumar & Suresh, 2016;

Florina Andreescu et al., 2018; Srinivasan et al., 2021). Nevertheless, it is also associated with a series of drawbacks such as low dimensional accuracy, prone to bacterial plaque accumulation, inadequate mechanical strength, and irritation caused by uncured monomer (Rashid et al., 2015; Einarsdottir et al., 2020). These drawbacks underscore the disadvantages associated with this material.

As the demand for dental prostheses has grown exponentially in recent years, various methods of dental prostheses fabrication have emerged. This includes subtractive manufacturing (SM) through Computer Numerical Control (CNC) milling and additive manufacturing (AM) through three-dimensional (3D) printing. These methods of manufacturing that enable digital design and fabrication are known as digital dentistry (Anadioti et al., 2020). Digital dentistry has revolutionized the fabrication process of dental prostheses by significantly improving precision, workflow speed, and overall efficiency. Unlike conventional methods, where dental prostheses were manually designed and crafted for each patient, digital dentistry leverages advanced technologies such as computer-aided design and computer-aided manufacturing (CAD-CAM) systems to create highly accurate and customized prostheses tailored to the individual's unique situation (Di Fiore et al., 2022).

Instead of taking an impression of the patient's oral contour, computer aided-design (CAD) employs a 3D scanner to capture the patient's teeth and oral structures digitally. The advantages of digital dentistry are manifold, for instance, it reduces the chances of human errors that may occur during manual fabrication, ensuring a higher level of accuracy and fit for the prostheses. Additionally, the digital workflow enables faster turnaround times, allowing patients to receive their dental prostheses in a shorter period with lesser visits to the dental clinic. Currently, SM and AM are the most

common digital method for fabricating the denture base. By utilizing advanced milling machines, the process of subtractive milling allows for the creation of high-precision dentures. Dentures fabricated through subtractive milling exhibit several advantages, including high mechanical strength, minimal shrinkage, and exceptional accuracy (Kalberer et al., 2019). However, this manufacturing method is not without its drawbacks, including the high cost of fabrication, wear of rotary burs, and significant material wastage of up to 90% (Gad et al., 2022).

On the other hand, AM also commonly known as 3D printing, offers significant advantages in fabricating intricate geometries, such as the complex contours of dentures. The layer-by-layer approach in 3D printing enables the creation of precise and intricate structures, including hollowed models and microscopic features, with ease and accuracy (P. Li et al., 2022). Moreover, the 3D printing process produces little to no wastage and is capable of producing multiple parts simultaneously. Numerous additive manufacturing technologies are capable of creating dental prostheses, including fused filament fabrication (FFF), selective laser sintering (SLS), vat polymerization, and so forth. Among these AM technologies, vat polymerization stands out as the most favourable method for fabricating denture bases owing to its high precision, fast fabrication, and suitable printing material (Puškar et al., 2019; Chhabra et al., 2022).

Vat polymerization, commonly known as photo-curing 3D printing, is the first 3D printing technology invented by Charles Hull in 1983 (Jockusch & Özcan, 2020). This 3D printing technology employs the photopolymerization technique to activate and polymerize the photosensitive resin with ultraviolet (UV) or visible light (Zhu et al., 2021). Vat polymerization can be categorized into various techniques based on different principles of pattern illustration and control systems. As of now, stereolithography

(SLA), digital light processing (DLP), and liquid crystal display (LCD) are the most common and popular vat polymerization techniques used for fabricating dentures (Quan et al., 2020; Chen et al., 2021). These vat polymerization techniques can swiftly produce high-precision dentures at a lower cost compared to the conventional and SM method. Multiple studies have consistently shown that 3D-printed dentures exhibit superior retention and stability when compared to conventional dentures (Cristache et al., 2020; Tian et al., 2021). Furthermore, patients express higher levels of satisfaction with 3D-printed dentures, attributing their comfort and suitability for extended wear as significant factors in their preference (Florina Andreescu et al., 2018).

1.2 Problem Statement

There is a series of factors that can affect the physical, mechanical, and biocompatibility properties of the 3D-printed denture. For instance, the layer height, printing orientation, printing technology, printing materials, post-processing procedure and so forth (Zhang et al., 2019; Unkovskiy et al., 2021; Wang et al., 2021). Every factor can ultimately affect the performance and appearance of the 3D-printed denture base. Therefore, comprehensive characterization with different factors needs to be carried out to determine the appropriate print setting and procedure to optimize the performance, aesthetic, and dimensional accuracy of the 3D-printed denture base. In a recent study, the author compared the flexural properties and cytotoxicity of interim materials printed using DLP and LCD technology (Chen et al., 2021). It concludes that the photosensitive resin designed for the DLP 3D printers can be printed on an LCD printer with appropriate settings. Moreover, the LCD-printed interim materials have comparable flexural properties in comparison with the DLP-printed interim with a sufficient amount

of post-polymerization. In another study, the author compared the flexural properties and accuracy of different 3D-printed denture base resins printed on SLA and DLP printers. The results showed that the SLA printed part has the highest accuracy error compared to the DLP, whereas the flexural strength of both was comparable (Al-Qarni & Gad, 2022). However, since the author used different proprietary resins for each specific 3D printer, it was uncertain whether the mechanical properties were affected by the material itself or by the printing technology. Whilst there are studies conducted to characterize the properties of 3D-printed denture bases, there is data scarcity regarding the effect on 3D-printed denture bases printed with different vat polymerization techniques.

1.3 Research Questions

This study aimed to understand the following research questions.

- 1) Can the 3D printing denture base resin designed for the DLP technique be printed on other vat polymerization techniques?
- 2) What is the effect of different vat polymerization techniques on the 3D-printed denture base resin in terms of mechanical properties?
- 3) What is the effect of different vat polymerization techniques on the 3D-printed denture base resin in terms of physical properties?
- 4) What is the effect of different vat polymerization techniques on the 3D-printed denture base resin in terms of biological properties?

1.4 Objectives of the Study

The main objective of this study was to examine the printability of designated DLP resin on different vat polymerization techniques and evaluate the physical, mechanical, and biological properties of 3D-printed denture bases fabricated with different vat polymerization techniques.

1.5 Specific Objectives

- i. To determine the printability of the designated DLP 3D printing denture base resin on SLA and LCD.
- ii. To evaluate the fracture toughness, surface hardness, and flexural strength and modulus of the designated DLP 3D-printing denture base resin fabricated with SLA, DLP, and LCD techniques.
- iii. To analyse the surface morphology, water sorption and solubility, and degree of conversion of the designated DLP 3D-printing denture base resin fabricated with SLA, DLP, and LCD techniques.
- iv. To evaluate the fungal adhesion of *Candida albicans* and cytotoxicity of Human Gingival Fibroblasts (HGFs) on the designated DLP 3D-printing denture base resin fabricated with SLA, DLP, and LCD techniques.

1.6 The Significance of the Study

The vat polymerization technology is the most common approach in 3D printing dental prostheses, especially denture bases. Understanding the impact of different vat polymerization techniques on the mechanical, physical, and biological properties of 3D-

printed denture bases offers valuable insights for optimizing the additive manufacturing process for dentures. This knowledge paves the way for a more informed and effective approach to fabricating denture bases using vat polymerization techniques. Moreover, the printability of a designated DLP resin on different technologies 3D printers will be elucidated in this study, allowing the possibility of close system 3D printing resin to be printed on open system 3D printers.

