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Additive Manufacturing of Dentures Using Polyether Ether Ketone

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Abstract

Conventional dentures are manufactured in a complex, time-consuming casting process that requires several patient visits for manual adjustments. Additive manufacturing is a promising alternative to reduce denture manufacturing times, labour costs, and material waste; however, additively manufactured dentures typically have lower strength than their conventionally manufactured and milled counterparts. One method to improve the strength of 3D printed dentures is to adopt new materials. Most additively manufactured dentures are made from polymethyl methacrylate (PMMA) using digital light processing or stereolithography printers. PMMA is popular due to its good aesthetics, low cost, biocompatibility, and ease of processing; however, PMMA is also brittle and susceptible to fracture from flexural fatigue. An alternative is to use polyether ether ketone (PEEK), which is highly biocompatible and non-absorptive, making it suitable for use in the oral environment. Furthermore, PEEK is more ductile and has a higher flexural strength than PMMA, thus offering improvements to mechanical performance. Typically, PEEK dental appliances are milled, but since PEEK is a thermoplastic, it can also be manufactured via fused deposition modelling (FDM) 3D printing. Though PEEK has numerous advantages, it has only seen limited use in dentistry due to its poor aesthetics, high cost, and manufacturing difficulty. This study investigates the feasibility of 3D printing denture teeth using natural and titanium dioxide (TiO_2)-reinforced PEEK. TiO_2 reinforcement gives the PEEK a whiter colour, making it aesthetically suitable for teeth, while a thin layer of highly amorphous PEEK appears translucent, and contributes to a more natural-looking tooth when printed overtop of the TiO_2-reinforced PEEK. The focus of this study is the optimization of FDM manufacturing parameters to maximize the dimensional accuracy and mechanical performance of 3D printed PEEK and TiO_2-PEEK composites. Unlike most PEEK optimization studies that prioritize crystallinity for strength, this work aims to maintain low crystallinity in the natural PEEK to enhance translucency, aligning with denture requirements. Parameters, i.e., the nozzle temperature, bed temperature, chamber insulation, print speed, layer height, and printing orientation were optimized using the Taguchi method. Mechanical performance was evaluated by performing 3-point bending and compression tests on standardized samples, while dimensional accuracy was evaluated by comparing printed samples to their corresponding CAD models using a custom geometric analysis tool. The investigations have found that the cooling rate, determined by the chamber insulation, nozzle temperature, and bed temperature played a key role in determining the crystallinity of PEEK while the printing orientation heavily influenced dimensional accuracy.