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BINDER JET PRINTING OF PARTIAL DENTURE METAL FRAMEWORK FROM METAL POWDER

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Introduction

Rapid prototyping technologies are the most extensively applied methods based on additive manufacturing (AM) principles, but the first complex-shaped AM parts are already in serial production for commercial aircrafts [1]. The main advantage of rapid prototyping includes the fabrication of models and prototypes for concept assessment as well as functional testing of new products. AM methods have been used to manufacture dental prostheses such as removable partial denture frameworks that retain artificial replacement teeth [2], implants [3], and substructures for crowns and bridges [4]. Additive manufacturing, in general, is best suited for production of small to medium parts with complex geometry in which customized design is desired. Recently, binder jet printing has attracted attention for biomedical applications [5]. Binder jet printing (BJP) is an additive manufacturing method in which powder is deposited layer-by-layer and selectively joined in each layer with binder. Binder jetting is a fast, low-cost manufacturing stress-free structures with complex internal and external geometries.

In this study, binder jetting is used to produce metal frameworks for removable partial dentures. An existing framework was scanned using micro-computed tomography and printed. Sintering resulted in >99% density with controlled shrinkage. Presented results demonstrate that binder jetting can be used to produce thin walled complex-shaped overhanging structures as shown here on a denture metal framework model.

Methodology

The micro-CT scanned 3D model of the used supplied partial denture framework is shown in Figure 1a. The partial denture was visualized with a Bruker SkyScan1272 µCT at 100 kV and 100 µA with a 0.11 mm Cu filter, averaging of 10 frames, and angular range of 0°–180° with 0.2° rotation step. It is seen that there are many complex, overhanging and small-diameter parts in the framework such as occlusal, clasp, major/minor connectors and retentive arms. Gas atomized Ni-based alloy 625 powder from Carpenter Technology Corporation with an average particle size of 32 µm was used as feedstock powder (see Figure 1 b-c).

A binder jet printer was used to print the denture with the following printing parameters: layer height of 100 µm, recoat speed of 130 mm/s, oscillator speed of 2050 rpm, roller speed of 250 rpm, roller traverse speed of 15 mm/s, and drying speed of 17 mm/s [6,7]. The printed parts were cured at 175 °C in a box furnace and then sintered in a Lindberg tube furnace embedded in alumina powder under vacuum at a holding temperature of 1285 °C for 4 h (detailed information in [8,9]).

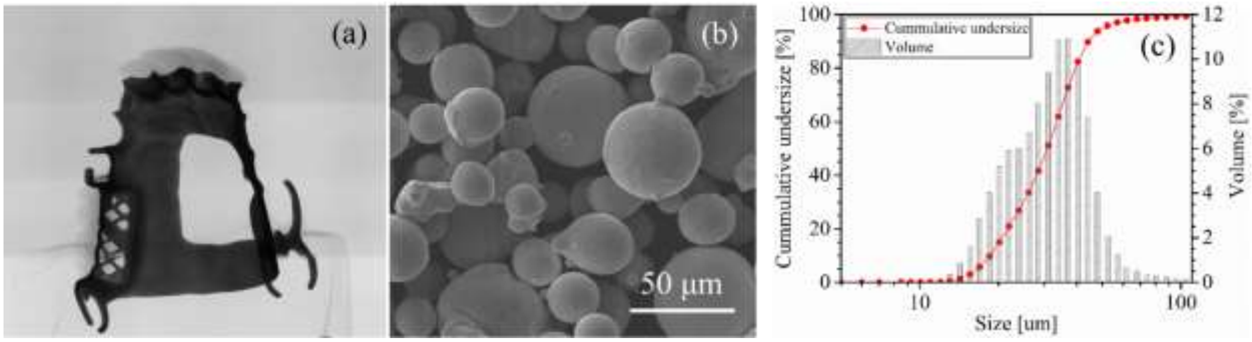

Figure 1. (a) The scanned 3D model obtained from the denture framework using µCT, (b,c) SEM and particle size distribution of the used powder for printing.

Results and Discussion

Figure 2 illustrates the BJP part, sintered and polished dentures. Detailed information about the sintering conditions, microstructural development, mechanical properties and densification for binder jetting of used alloy in this study can be found in [9,8]. 17% dimensional change was seen in the sintered control sample compared to the as-printed one (Figure 2). Additionally, our measurements on 6 different parts of the sintered denture showed average dimensional change of 15%. This must be considered when designing denture frameworks for binder jetting. BJP can be used to print complex shape structures with overhangs and complex internal features without any residual stresses that might cause distortion, crack initiation or even fracture. During the required post-print sintering process, full density or a desired porosity of between 40% and 0% can be achieved. This is in contrast to laser or electron beam melting AM methods, which always produce near full density parts, and require a stress-relief post-processing step because of residual stress build-up during the printing causing distortions, crack initiation and potential failure [2,10].

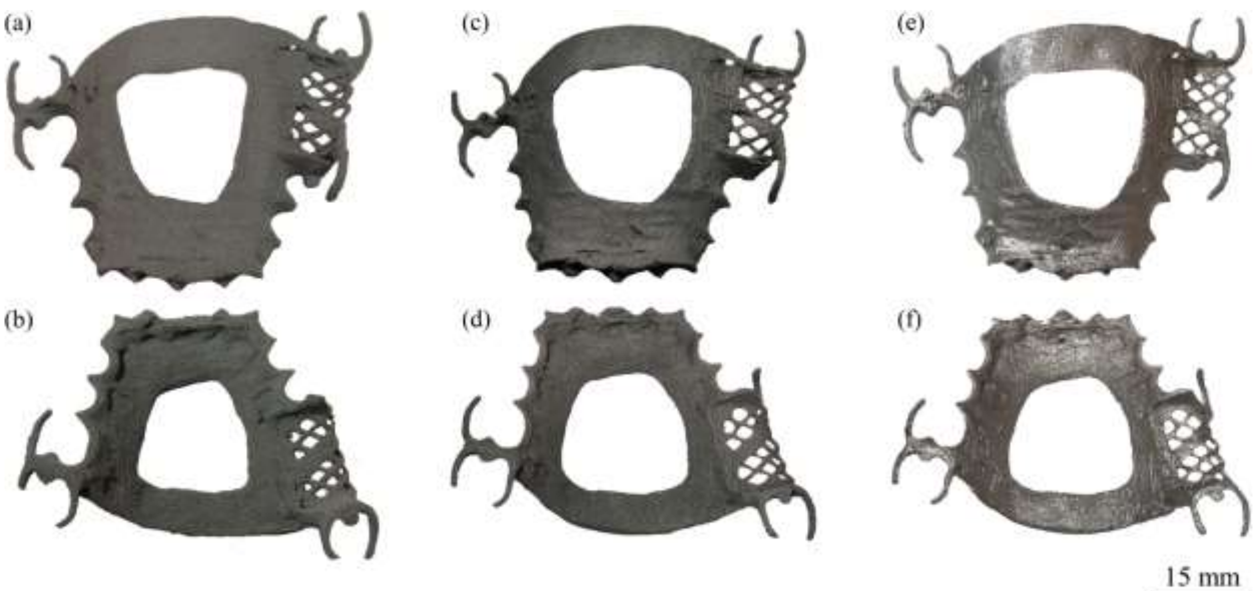

Figure 2. Top and bottom view of the (a,b) printed, (c,d) sintered, and (e,f) polished denture.

Conclusion

This study shows that binder jetting can be a potential method for manufacturing complex geometries with fine features in dentistry and in general. With the advantage of minimum material waste, easy powder reuse, and a no-tooling requirement, BJP offers an economical method to manufacture parts with complex shapes, overhangs and no thermal stresses with large build volumes. We aim to extend BJP method for other dental materials such as Ti-based and Co-Cr-Mo materials. Therefore, more research is necessary to acquire a thorough understanding of the correlation between the property of the powder, printing parameters and mechanical properties of the resulting parts, to ensure repeatability and consistency in the final product.

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