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Progress in Metal Additive Manufacturing towards a Wide Implementation in Dentistry

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In recent years, the availability of high power lasers has enabled the full melting (FM) of raw materials, as in the case of selective laser melting (SLM), and hence, has overcome the necessity of a binder [1]. Thus, the FM allows the fabrication of parts with alloys suitable for dental applications. SLM eliminates many physical stages, required in the time-consuming investment casting process, by offering speed of the manufacturing process for bespoke metallic devices, such as denture frameworks and implant abutments [2-5]. The manufacturing process is solely based on dental and medical CAD data, which are designed on virtual anatomical patterns received from high-resolution dental scanners and CT, CBCT, MRI, photogrammetry, or surface scan data [6,7].

Cobalt-chromium (Co-Cr) and titanium alloys remain by far the most widely used alloys for affordable prosthodontics treatment. Documented studies show SLM fabricated parts possess adequate mechanical properties for clinical use [8-10]. In addition, available data indicates superior properties, in comparison to cast, for both tensile strength and fracture toughness [4,11-13]. These results show that a direct substitution of investment casting with SLM in the dental area is uncritical. In the assessment of biocompatibility, corrosion data, which forms an excellent adjunct to cytotoxicity studies, show that SLM fabricated samples have lower ion emission rates than cast ones (Fig. 1) [2,4]. Cytotoxicity studies also proved them safe, non-irritant and nontoxic on oral tissues and the body as a whole [14,15].

However, the design and dimensioning of components can be very challenging, as the layer-wise generation process results in anisotropic material properties, which are highly volatile to the manufacturing conditions [16]. For components designed close to the material limits, the dimensioning state has to account for the anisotropic properties, in both, the elastic and elasto-plastic range, including the stress-concentration effects of localized, inherent imperfections [17]. Currently, the surface roughness of 'as-built' SLM parts appears of insufficient quality for dental applications [18]. It is worth stating that the particular surface characteristics, and consequently their roughness, depend on the alignment and the positioning in the built space [19]. The choices available in post processing technologies to overcome the challenges of insufficient surface quality, while still maintaining the geometric flexibility in the built parts, are limited. On a positive note, recent studies have advanced from a proof of concept stage to polish the surface of SLM components with a laser; a process that could eliminate manual polishing altogether [20,21].

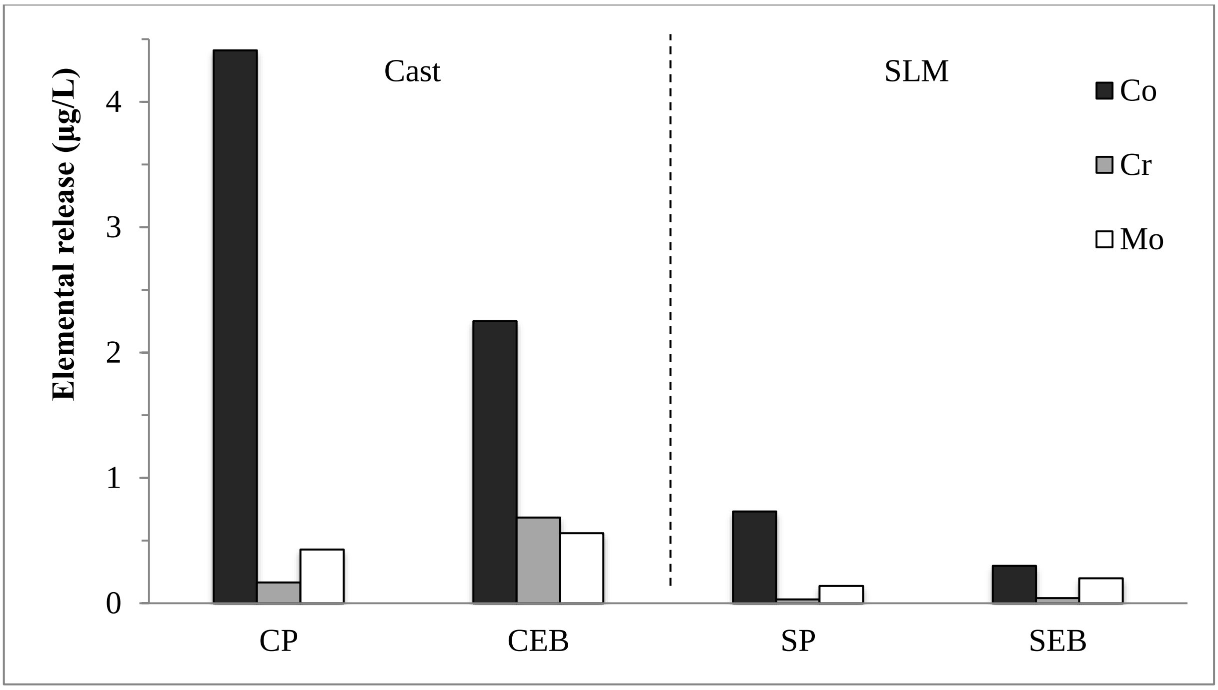

Figure 1: Elemental release of Co-Cr-Mo in artificial saliva after 42 days in accordance with ISO 10271 on: CP = cast and polished; CEB = cast and electro-brightened; SP = SLM-fabricated and polished; SEB = SLM-fabricated and electro-brightened; adopted from [4]

Conclusion

The SLM process, although high-priced to acquire, offers increased speed and flexibility in dental technology. Likewise, the SLM process, being controlled digitally, offers a standard method for the production of dental devices, which is likely to be much closer to the manufacturer's specifications than investment casting that is fraught with fabrication steps and operator variations. Nevertheless, further studies are required to understand the parameters that influence the physico-mechanical properties of SLM fabricated components.

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