Rapid manufacturing of alumina samples by combining additive manufacturing and microwave thermal treatments

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The aim of this study is to combine additive manufacturing and rapid thermal treatment (debinding and sintering) to obtain ceramic samples with small dimensions and complex and/or customizable shape in a few hours, while keeping mechanical properties similar to those obtained after conventional shaping and sintering. Among the additive shaping techniques, stereolithography was chosen for its high resolution, its ability to produce raw parts of high relative density and for its reproducibility. Thus, a resolution of 50 µm can be reached and the green samples obtained can be easily handled in order to proceed to the thermal post-treatment. The dimensions of these pieces are limited to about 3 cm edge. Regarding debinding and sintering, microwave heating was chosen. Indeed, this process allows very fast heating rates (about 200°C/min), low energy consumption and permits a total freedom in terms of shape of the parts to be treated. In order to optimize the effect of the electromagnetic field and to limit the energy consumption, a single-mode resonant microwave cavity at 2.45 GHz was used. However, this choice limits the dimensions of the sample to about 3.5 cm. Considering the characteristics of both shaping and heating processes, the aimed applications must be consistent with the size of the parts obtained. That is why the choice was made to focus on the development of dental implants and alumina bone substitutes for biomedical applications. First, the coupling of shaping and sintering techniques was validated. Then, the debinding step, also critical in terms of manufacturing time, was investigated. Thus, in-situ microwave debinding has made it possible to obtain parts in reduced times. After determining the suitable experimental parameters, physical, microstructural and mechanical properties of the obtained samples were characterized. It has been shown that the mechanical properties achieved after coupling the two rapid processes remain lower than those obtained after conventional manufacturing, but consistent with the aimed biomedical applications, while reducing the manufacturing time by a 30 to 40%.