Abstract

The manufacturing of biomedical implants is a challenging task owing to variation in shape and size of the implants. Close-fit of the implants is requirement to achieve higher success rate in clinics. Dental crown and lower jaw bone are such components where variation in size and shape is always encountered. In this perspective, standardization and improvement in materials design, development and processing have become essential requirements for production of quality implants.

The present study combines the development of materials, designing and processing aspects for near net shape forming of patient specified implants like dental crown and lower jaw bone by reverse engineering approach through generation of solid model from scan data. In addition, Computer Numerical Control (CNC) machining of sintered ceramics is another significant challenge to fabricate customized implants by reverse engineering approach due to their high hardness and low fracture toughness. Thus, pre-requisite is to develop machinable green ceramics which can be near net shaped into dental crowns/mandible within short time durations. In this context, poly(maleic acid) (PMA) was explored as an anionic long chain dispersant for preparation of highly loaded (55 vol %) aqueous alumina slurry. An optimized alumina slurry composition was formulated through rheological optimization to fabricate machinable alumina compacts in an environmentally friendly process, where egg albumin and sucrose were used as binders. Further, customized diamond embedded tools were designed and fabricated through nickel electroplating on mild steel shanks for green machining of alumina compacts. A customized sample holder of stainless steel was manufactured for holding the green alumina samples during CNC machining. Finally, customized alumina based monolith crowns were successfully fabricated through combined vertical and rotary axis machining (four axis CNC machine of cylindrical green alumina compacts) using optimized machining parameters. Evaluation of mechanical properties, wear and Weibull modulus study of the sintered alumina samples revealed that net shape forming via green machining could be a viable method for intended applications. The machined and sintered alumina samples were characterized for surface quality, anisotropic shrinkage and microstructure examination. From the shrinkage analysis, it was evident that the linear shrinkage associated with sintering was ~ 15 % and isotropic in nature which facilitates close-fit of the size and shape as per the customized design. Veneering procedure of the sintered alumina crown was explored using sodium tripolyphosphate (STPP) solution for aesthetic purpose and the veneered alumina crowns appeared similar to natural tooth.

Another aspect of this study was to prepare alumina fibers through wet spinning followed by sintering for preparation of fiber scaffold and fiber reinforced polymer composite. Customized crowns and mandibles were fabricated using alumina fiber reinforced polymer composite via reverse engineering. The alumina fiber reinforced resin based composite crown was fabricated either through direct filling into the customized mold or direct CNC machining of cylindrical alumina fiber based resin composite using diamond embedded tool. Prior to fabrication of hybrid composite based mandible, a wooden pattern of mandible was formed via CNC machining by diamond embedded tool using 3D laser scan image data which was subsequently used for preparation of silicon rubber mold and the alumina fiber blended with resin filled into the mold to obtain the final product. The composites were characterized for microstructure, mechanical properties and wear analysis. Further, in vitro cell culture study using HaCaT cells on the machined sintered alumina and composites revealed that the samples were significantly cytocompatible.

Keywords: Green machining, Diamond embedded tool, Net shape forming, CNC machine, Weibull modulus