PROCESS FOR PRODUCING CERAMIC PORCELAIN SLURRY FOR 3D PRINTING APPLICATIONS

Technical Field

The present utility model concerns ceramic materials for additive manufacturing, particularly to a ceramic slurry composition comprising porcelain and organic resin suitable for use in three-dimensional (3D) printing processes such as stereolithography (SLA) for the fabrication of dental prosthetics.

Background of the Utility Model

The advancement of additive manufacturing (AM) in dentistry has revolutionized the fabrication of dental prosthetics. Typical AM techniques used for ceramics include material or paste extrusion and lithography-based ceramic manufacturing. While traditional methods for producing porcelain dental crowns rely on subtractive techniques that are time-consuming, material-intensive, and dependent on manual expertise, AM offers patient-specific and customizable products with time efficient and lower wastage processing techniques.

Much research explores use of ceramic slurry in AM. Stereolithography (SLA), a precise and high-resolution AM technique, has gained attention for its ability to produce intricate ceramic dental restorations with enhanced precision and material efficiency. This AM technique used laser to produce 3D objects, As the laser hits the ceramic suspension, it solidifies and cures through photopolymerization, thereby creating a 3D structure layer by layer.

Multiple studies have proven the effectiveness of using SLA in producing dental applications. Bai et al. (2020) showed that SLA printed zirconia crowns have comparable mechanical properties to conventionally milled crowns. Porcelain dental crowns offer superior aesthetics, biocompatibility, and durability, making them ideal for restorative dentistry. Porcelain-based materials include feldspathic porcelain, high alumina porcelain, lithium disilicate, and zirconia. Among these, feldspathic porcelain remains the most used material for dental crowns because of its natural tooth-like appearance and translucency.

CN111548120A relates to the field of ceramics and processing methods thereof, particularly to 3D printed volcanic pit-shaped texture ceramic and a processing method thereof. The 3D printed volcanic pit-shaped texture ceramic is characterized in that a blank comprises the following components in parts by weight: 20-25 parts of kaolin, 10-12 parts of aluminum oxide, 5-8 parts of zirconium oxide, 10-12 parts of calcium carbonate, 6-7 parts of a surfactant, 50-60 parts of methyl acrylate light-cured resin, 5-7 parts of a dispersing agent, 10-20 parts of hydroxyapatite powder and 30-40 parts of water.

WO2024106609A1 relates to a ceramic slurry composition for 3D printing, and a method for producing a high-strength ceramic structure using same, and more specifically, provides a ceramic slurry composition for 3D printing, and a method for producing a high-strength ceramic structure using same, the ceramic slurry composition comprising: 60-80 parts by weight of ceramic particles coated with an inorganic binder precursor solution comprising sodium (Na); 15-35 parts by weight of a photocurable resin; and 0.1-5 parts by weight of a dispersant, wherein the photocurable resin comprises 80-90 parts by weight of a photopolymerizable monomer, 1-10 parts by weight of a photoinitiator, and other additives, and the composition is photopolymerized by being irradiated with light, and then aged at 50-200°C for 1-3 hours, thereby having enhanced strength.

The use of locally sourced feldspar, silica, and kaolin have been explored to reduce costs and promote sustainability in dental material production. Research has indicated that these raw materials can be optimized for dental applications through appropriate processing and sintering techniques.

Summary of the Utility Model

The present utility model relates to a ceramic slurry that is primarily a mixture of porcelain and organic resin. The method of preparation includes mixing of feldspar, silica, kaolin clay, and alumina by milling with water and drying to obtain a homogeneous mix of porcelain. Then, porcelain is modified with polymeric additives such as polyethylene glycol, oleic acid, and/or stearic acid to make it suitable for mixing with organic liquid resins such as polylactic acid, polymethylmethacrylate or any acrylate-based resin. The process of modification involves ball milling with solvent such as methanol or isopropyl alcohol and drying using oven for 24 to 48 hours. The powder obtained using ball mill is mixed with the resin at a ratio of 40-60% w/w porcelain to 60-40% w/w organic resin. The porcelain may further comprise 2-5% w/w of polymeric additives such as polyethylene glycol, oleic acid, and/or stearic acid to improve compatibility.

The main objective of the present utility model is to provide a ceramic slurry for 3D printing using stereolithography apparatus for dental applications. Furthermore, it is an object of the present utility model to provide a process for making and modifying porcelain that is suitable for photocurable resins for 3D printing. It is also an object of the present utility model to provide a low-cost and locally available ceramic slurry.

Detailed Description of the Utility Model

Feldspar, silica, kaolin clay, and alumina are used as the precursor materials in preparing the base material of the ceramic slurry which is porcelain. Precise formulation of the precursor materials is weighed and mixed such that the silica makes up the most of porcelain and alumina is added to obtain high quality and white porcelain. Production of porcelain follows these steps: (a) mixing of 15-20% feldspar, 50-60% silica, 5-10% clay, 15-20% alumina in a ball mill chamber, (b) milling for 24 to 48 hours, and (c) oven-drying.

To make the porcelain compatible to the organic resins such as polylactic acid, polymethylmethacrylate, or any acrylate-based resin, polymeric additives were used to attach onto the surfaces of the porcelain powders. Polymer additives such as polyethylene glycol, oleic acid, and/or stearic acid were used. Preferably, the composition of porcelain comprises 95-98% of inorganic materials and 2-5% of organic additives. Production of modified porcelain follows these steps: (a) mixing of inorganic powders and organic additives in a ball mill chamber, (b) milling for 24 to 48 hours with methanol or isopropyl alcohol, and (c) oven-drying.

Readily available photocurable resins that are mainly polylactic acid, polymethylmethacrylate or any acrylate-based resin is used as matrix for the slurry. Preferably, the resin is compatible to commercially available stereolithography apparatus to produce 3D objects. The porcelain is added into the resins by ball milling for 24 to 48 hours. Preferably, the porcelain to resin ratio is 1:2 to 2:1. To use for 3D printing, the slurry is allowed to age for 5 to 8 hours to remove gases or air bubbles acquired during milling. Another way to remove trapped air is by using a degassing machine.

Examples of Characterizations

1.1 Physical Properties

The sintered porcelain ceramic at temperatures between 1250 °C to 1300 °C was characterized by determination of bulk properties (shrinkage, water absorption, porosity, and bulk density), cold crushing strength based on ASTM Designation C 373-72 (ASTM standards, 1992). The shrinkage is approximately 17%, the water absorption and porosity are at 0%, and the bulk density is 1.8.

1.2 Mechanical Performance

Mechanical performance of the sintered porcelain ceramic at 1280 °C implant was evaluated via universal testing machine (Shimadzu AGS-X, 50 kN static load cell). The compressive strength of the sintered porcelain falls between 300 MPa and 400 MPa. Meanwhile, the flexural strength falls between 100 MPa and 200 MPa.