Form8

ABSTRACT OF DISSERTATION

Title	Application of porous titanium in prosthesis production using a moldless process: Evaluation of physical and mechanical properties with various particle sizes, shapes, and mixing ratios （モールドレス成形によるチタン多孔体の補綴装置への応用：物理的および機械的性質における粉末粒径、形状と混合比率が及ぼす影響）
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Introduction

While titanium can be used in dental implants, its use in dental prosthesis has been limited because the conventional casting for titanium is made challenging by its high melting point and the risk of oxidation. Recently, titanium using CAD/CAM systems have developed as a framework material for implant superstructure. This process requires equipment, operation technology, and time. Selective laser sintering or selective laser melting offers the advantage of using titanium powder to produce a metal framework, due to its rapid manufacturing rate. However it is difficult to modify the surface of titanium frame after modelling, since few correction methods are available for application in clinical settings. Hence, a new manufacturing process is required for application of titanium in prosthesis production. This study focuses on the production method of porous titanium that we have developed, and on its validity for prosthesis application. This method using a moldless process enables a simple manufacturing process that produces a mixture of high formability without using a mold and conventional casting operation. This study aimed to evaluate the physical and mechanical properties of porous titanium using a moldless process with various particle sizes, shapes, and mixing ratio of titanium powder, for the application to prosthesis production.

Materials and Methods

Commercially pure Ti powder with different particle sizes, shapes, and mixing ratios were divided into five groups. Group 1: < 45 μm (irregular), Group 2: < 45 μm (spherical), Group 3: < 150 μm (spherical), Group 4: mixed powder (75 wt% < 150 μm in spherical shape and 15 wt% < 45 μm in irregular shape), and Group 5: mixed powder (80 wt% < 150 μm in spherical shape and 10 wt% < 45 μm in irregular shape). A 90:10

wt% mixture of Ti powder and inlay wax were prepared manually at 70°C to obtain a green body. After debindering at 380°C, the specimen was sintered in Argon atmosphere at 1100°C for 1 h. The particle size distribution, green density, linear shrinkage ratio, porosity, bending strength and shear bonding strength were evaluated. The sintering result of each specimen was observed using SEM.

Results

Groups 1 and 2 presented a narrow particle size distribution (0-25 μm and 0-45 μm, respectively). Groups 3, 4 and 5 presented a broad size distribution (0-110 μm). The linear shrinkage ratio (2.1-14.2%), green density (2.7-3.1 g/cm^3), porosity (17.7-38.5%), bending strength (106-428 MPa) and shear bond strength (32-100 MPa). Group 1 showed the highest linear shrinkage ratio under the influence of the lowest green density. However, Group 1 presented the lowest porosity followed by the highest bending strength and shear bond strength. The fracture mode of the sintered specimen after shear bond strength test was cohesive for all the groups and occurred within the sintered body close to the interface between titanium plate and porous titanium.

Discussion

The linear shrinkage ratio increased with decreasing particle size. While the linear shrinkage ratio of Groups 3, 4, and 5 were approximately 2%, Group 1 showed the highest shrinkage of all. This can be explained by the fact that small particles have a much higher surface energy, and are therefore, easy to sinter. The irregular-shaped particles showed high shrinkage ratio compared to the spherical-shaped ones because of low green body density related to poor packing property of the powder. The substitution of irregular small particles for spherical large particles resulted in an increase in the green body density and decrease in the porosity. The particle size and mixing ratio play an important role in the porosity and the pore morphology. Group 1 and 2 presented low porosity followed by higher strength. The decrease in the porosity increased the bending strength. These results indicate that the porosity of porous titanium was associated with the bending strength. The shear bond strength was particle-size dependent. The substitution of irregular small particles for spherical large particles improved shear bond strength.

Conclusion

Physical and mechanical properties required for prosthesis were dependent on the particle sizes, shapes and mixing ratios of titanium powders. This production method can be applied to the prosthetic framework by selecting the appropriate material design. Further studies are needed to improve the strength without the increase of shrinkage rate in order to apply it for prosthesis production.