Strengthening of Ti-6Al-7Nb Alloy for Dental Narrow Implants

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Statement of Purpose: Ti-6Al-7Nb alloy is widely used in medicine, such as artificial hip joints, spinal fixators, and dental implants, due to its lightweight and superior corrosion resistance. On the other hand, dental narrow implants are applied in the situations with limited horizontal space. Therefore, thin diameter and high strength are required for the narrow implants. The mechanical properties of Ti-6Al-7Nb alloy are governed by its microstructure, of which refinement increases the strength. However, it is impossible to achieve a significant strengthening of the Ti-6Al-7Nb alloy by a conventional heat treatment, such as quenching and aging. Here, high-pressure torsion (HPT) is a processing technique to produce ultrafine-grained structures through severe plastic deformation, even for hard and low-ductile metallic materials. HPT can enhance the strength with keeping almost the same elongation. In this study, Ti-6Al-7Nb was deformed by HPT for strengthening of the alloy.

Methods: A commercial Ti-6Al-7Nb alloy (ASTM F1295) was employed in this study. Rods of the alloy with a diameter of 10 mm were received after hot rolling and annealing. A rod was sliced to disks with a thickness of 0.8 mm. HPT was conducted at room temperature under pressures of 2 and 6 GPa with a rotation speed of 1 rpm for 1, 5 and 20 revolutions. Microstructure was characterized by transmission electron microscopy (TEM) and X-ray diffraction (XRD) analysis. TEM was operated at 100 kV for microstructural observation and for recording selected-area electron diffraction (SAED) patterns using Hitachi H-7100. The constituent phases were analyzed by XRD using an X-ray diffractometer with the Cu Kα radiation. Mechanical properties were evaluated by Vickers microhardness measurement and tensile test. The hardness was measured along the 12 radial directions from the center to the edge of each disk in incremental steps of 0.5 mm. Tensile specimens having a gage length of 1.5 mm, a width of 0.7 mm, and a thickness of 0.5 mm were cut. Each tensile specimen was mounted horizontally on grips and pulled to failure using a tensile testing machine with an initial strain rate of 2×10^{-3} s^{-1}.

Results: The initial microstructure consisted of equiaxed α phase grains with 5 μm in size and of the β phase located at their boundaries. It was confirmed that the volume fraction of the β phase is low as ~5%. **Figure 1** shows TEM micrographs and corresponding SAED patterns after HPT processing under 6 GPa through 5 revolutions. SAED pattern from the image show a ring pattern, indicating that the microstructure consisted of ultrafine grains having high angles of misorientations. The dark-field image revealed that the grain size of α phase was refined to about 100 nm. The hardness was 325 HV before HPT and increased after HPT with the increase of the distance from the disk center and the number of revolutions. The maximum value of 395 HV was attained in the disk after HPT processing under 6 GPa for 20 revolutions. Figure 2 shows the ultimate tensile strength and elongation to failure before and after HPT processing. All HPT-processed specimens were higher than that of 1050 MPa before the HPT. The value increased with increasing number of revolutions. The maximum value of 1250 MPa was attained after 20 revolutions. The values under 6 GPa showed higher values of about 1200 MPa for 1 and 5 revolutions, in comparison with those under 2 GPa. The elongation to failure after HPT processing decreased with increasing number of revolutions. However, the value under 6 Gpa for 1 and 5 revlutions is almost the same as that before HPT processing. It is found that the tensile properties are improved by application of 6 GPa through moderate numbers of revolutions in the HPT processing.

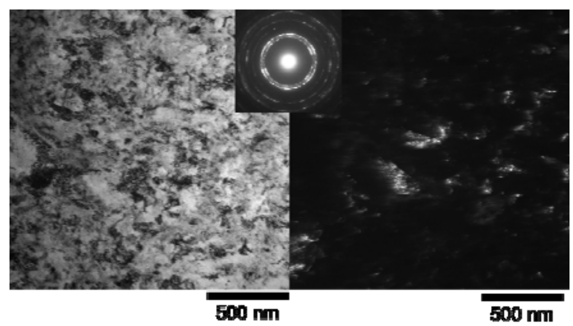

Figure 1. TEM image and SAED pattern of Ti-6Al-7Nb alloy processed by HPT under 6 GPa through 5 revolutions.

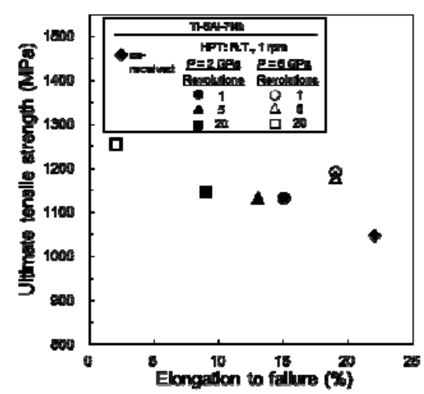

Figure 2. Ultimate tensile strength and Elongation to failure of Ti-6Al-7Nb before and after HPT processing

Conclusions: After HTP processing of a Ti-6Al-7Nb alloy, both large strength of 1200 MPa and large elongation of 19% were simultaneously obtained. This material shows excellent mechanical property for dental narrow implant body.