A three-dimensional finite element study on the biomechanical property of TiNb alloy with electrochemical treatment

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A dental implant as a screw type biomaterial is a functional load transfer structure to substitute for lost or partially damaged teeth. The requirements of ideal biomaterials using for implants need to satisfy both biomechanical and biocompatible properties. However, the conventional titanium dental implants with uniform structure cannot meet all these requirements.

Several studies show that major reasons for implant failure are due to insufficient mechanical bounding and transfer between the implant and surrounding bone tissue [1]. The insufficient mechanical bounding might result from insufficient osseontegration. The possibility of encapsulation formation on the smooth surface is higher than the porous surfaces. For long term success of dental implant application, porous coatings or materials can provide partial to complete bone ingrowth [2]. The insufficient mechanical transfer, overloading, will lead to the implant failure. The new metallic materials with proper mechanical property have been developed.

In our previous research, the titanium-niobium (TiNb) alloy with the porous structure is a potential candidate biomaterial for medical devices[3, 4]. The porous structure can be developed using anodization followed by cathodic pretreatment.

The mechanical behaviors of the TiNb alloys with anodization followed by cathodic pretreatment were investigated in this work. Experimental and finite element methods were used to evaluate the effect of porous TiNb alloys affecting interface of bone and implant. The elastic moduli of TiNb sheets with/ without electrochemical treatments were obtained using nanoindenter. The stain/stress distribution in bone around porous TiNb dental implants would be calculated using ANSYS with finite element models. The 3D FEMs of fully threaded cortical screws were created by using commercial software Solid Works 2007 and ANSYS Workbench 9.0 (Swanson Analysis System Inc., Houston, TX) as shown in figure 1. The graded porous material property and microstructure are denoted as solid-shell element type.

Figure 2 presents the experimental values of elastic moduli for TiNb alloys with/ without electrochemical treatment and Ti6Al4V. The elastic modulus decreases with porousity and oxide layers increments.

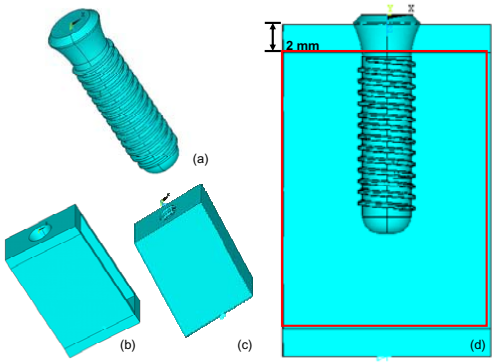

Fig. 1. Dental implant system: a) dental implant, b) cubic cortical bone, c) cubic trabecular bone, and d) configuration of the dental implant system

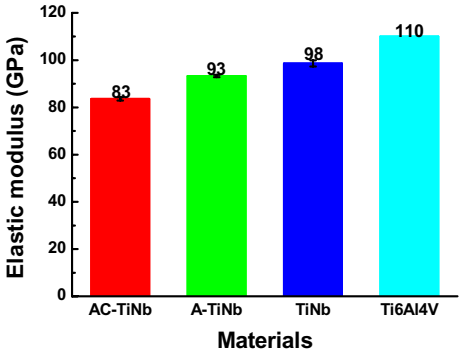

Fig. 2. Experimental elastic moduli of TiNb alloys with different treatment. AC is denoted anodization followed by cathodic pretreatment. A is denoted anodization. TiNb is denoted nontreatment.

References

1. Van Staden, R.C., Guan, H., and Loo, Y.C., "Application of the finite element method in dental implant research". *Comput Methods Biomech Biomed Engin*, 2006. **9**(4): p. 257-70.
2. Thelen, S., Barthelat, F., and Brinson, L.C., "Mechanics considerations for microporous titanium as an orthopedic implant material". *J Biomed Mater Res A*, 2004. **69**(4): p. 601-10.
3. Hon, Y.H., Wang, J.Y., and Pan, Y.N., "Composition/Phase Structure and Properties of Titanium-Niobium Alloys". *Materials Transactions*, 2003. **44**: p. 2384-2390.
4. Peng, P.W., Pan, Y.N., and Ou, K.L., "Effect of porous oxide films on characterization and bioactivity of titanium niobium alloy". *ECS Transactions*, 2006. **3**(19): p. 27.