Compatibility and concentration is suppressed after treatment. The current paper presents properties of NiTi that most other current medical metallic materials do not possess. Therefore, they have high potential for orthopedic surgery. Toxic nickel particulate debris released from these materials, however, remains a major concern particularly pertaining to orthopaedic implants for which fretting is always expected at the implant junction. Metallic debris is suspected to be associated post-operation complications such as implanted-induced osteolysis, pseudoarthrosis, subacute low-grade implant infection, late operative site pain and abnormal metal concentration in serum. In order to suppress nickel release and enhance the surface mechanical properties, we have developed a novel surface treatment to alter the surface chemistry of the materials. By using plasma immersion ion implantation (PIII), the surface mechanical properties of NiTi can be improved. In addition, the surface Ni concentration in serum. The current paper presents the corrosion resistance, surface mechanical properties, cyto-compatibility, and in-vivo performance of the nitrogen PIII materials and compare them to those of untreated NiTi, medical grade stainless steel and titanium alloy samples.

Introduction: Nickel-titanium discs with 50.8% Ni and balanced Ti were implanted with nitrogen plasma at 40kV and 200Hz. The elemental depth profiles and surface chemistry were determined by X-ray photoelectron spectroscopy. The surface hardness and elastic modulus were measured by nanoindenter. Corrosion resistance was assessed by a potentiometer. The amount of Ni released into the simulated body fluids after the accelerated corrosion tests were determined by inductively-coupled plasma mass spectrometry (ICPMS). The in-vitro biocompatibility was evaluated by culturing mouse osteoblasts expressing an enhanced green fluorescent protein on the surface of these materials. In in-vivo study, the samples were implanted into the rabbit femur and ilium for 2, 4 and 12 weeks. Untreated NiTi, medical grade stainless steel and titanium alloy were used as control.

Results: A layer of stable TiN about 200 nm thick is formed on the NiTi surface after nitrogen plasma implantation. Amorphous TiO, TiO₂ and NiO are found on the surface of the untreated NiTi. A large amount of Fe and small amounts of Cr, Mo, carbide and NiO are observed on the surface of the stainless steel. For the Ti alloy, only TiO and TiO₂ are detected. Compared to the untreated NiTi and stainless steel samples, the corrosion resistance of the nitrogen PIII sample is superior to that of those samples. However, it is slightly inferior to the Ti alloy (Fig. 1). The surface hardness and elastic modulus are enhanced and better than the untreated sample and stainless steel. The concentration of Ni leached into the simulated body fluids from the untreated sample is 30 ppm, whereas that from the nitrogen PIII is undetectable. In the stainless steel sample, Fe, Cr and Ni ions are detected. A small amount of Ti ions is found on the Ti alloy sample. No significant difference in the ability of cells to grow on the untreated and nitrogen treated NiTi is found. Cell proliferation on the stainless steel and Ti alloy samples is significantly less than that on the nitrogen treated sample (p<0.05). By using histological analysis, bone formation on the nitrogen PIII NiTi is observed to be better than that of the untreated NiTi and stainless steel and comparable to Ti alloy. A layer of fibrosis tissues is found on the untreated NiTi and stainless steel at an early time point, but it is not been found on the nitrogen NiTi (Fig. 2).

Discussion and conclusion: The overall properties of the nitrogen plasma treated NiTi samples are more superior, for instance, enhanced corrosion and wear resistance, insignificant amount of Ni release and high proliferation of osteoblasts. All these improvements can be attributed to the formation of titanium nitride on the surface. In addition, PIII differs from conventional coating. The plasma modified surface will not delaminate when the treated materials experience bending stress. Furthermore, the nitrogen NiTi also shows better bone growth in our animal studies. There is evidence that the PIII modified NiTi alloy is safe as orthopedic implants.

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