Nitrided Ti-6al-4v: A Catalyst for Increase Mineralization and Osteogenic Marker Expression

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Abstract

Titanium alloys are widely used in dental implants due to their excellent biocompatibility and mechanical properties. Plasma nitriding is one of the surface modifications that show more effectiveness than other methods. In this study, the plasma-based ion implantation (PBII) technique was performed on the surface of titanium alloy (Ti-6Al-4V, Ti64) using a mixture of nitrogen (N2) and argon (Ar), resulting in a plasma-nitrided surface (TiN-Ti64). The surface composition of the TiN-Ti64 was verified through X-ray photoelectron spectroscopy (XPS). TiN-Ti64 demonstrated superior hydrophilicity compared to Ti64. TiN-Ti64 exhibited higher surface hardness than the original surface. The biological responses of primary human alveolar bone cells (hAVs) were observed on the TiN-Ti64, revealing greater activation of cell adhesion and spreading compared to Ti64 and control group (glass coverslips). Moreover, the TiN-Ti64 significantly promoted cell proliferation compared with Ti64 and tissue culture plates. The mineralization of hAVs on the TiN-Ti64 showed a significant increase, almost 20% greater than that of Ti64. Furthermore, a significant upregulation of mRNA expression for osteogenic differentiation marker genes, including BMP2, OCN, OPN, and RUNX2, was observed in TiN-Ti64 compared with other conditions. In addition, the TiN-Ti64 exhibited antibiofilm activity against S. aureus. In conclusion, the TiN-Ti64, modified with the PBII technique utilizing a mixture of N2 and Ar, emerges as a promising alternative for surface modification in dental implant applications.

Keywords: Alveolar bone cells, Cell responses, Plasma-based ion implantation (PBII), Ti-6Al-4V

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Selected Publications

1. Krasaesin A., Pinijsuwan S., Boonruang C., Sriwattanapong K., Porntaveetus T., Osathanon T., Watanabe W., Jongwannasiri C., Manaspon C.*, 2024, "Nitrided Ti-6Al-4V: A catalsy for increase mineralization and osteogenic marker", **Journal of Biomedical Materials Research: Part A** (Accepted Dec 6th).
2. Kaewnisai S., Chingsungnnoen A.*, Poolcharounsin P., Jongwannasiri C., Manaspon C., Udomsom S., Ohgoe Y., 2023, "Effect of pulse frequency on the surface properties and corrosion resistance of a plasma-nitried Ti-6Al-4V alloy", **Materials Research Express**, Vol 10 (11), 116505.
3. Jongwannasiri C., Krasaesin A., Pinijsuwan S., Udomsom S., Boonprakong L., Eawsakul K., Osathanon T*, Manaspon C.*, 2023, "Diamond-like carbon (DLC)-coated titanium surface inhibits bacterial growth and modulates human alveolar bone cell responses in vitro", **Diamond and Related Materials**, vol 136, pp 110022.
4. Manaspon C., Krasaesin A., Udomsom S., Osathanon T., Watanabe S., Jongwannasiri C.*, 2023, "Investigating the influence of Titanium-Tantalum (Ti-Ta) thin film on alveolar bone cell response", **The 15th Biomedical Engineering International Conference (BMEiCON2023)**, Japan, Oct 28th-31st.
5. Krasaesin A., Udomsom S., Baipaywad P., Sriwattanapong K., Porntaveetus T., Osathanon T., Watanabe S., Jongwannasiri C., and Manaspon C.*, 2022, "The effect of plasma-nitrided titanium on mechanical properties and initial cell adhesion", **International conference and Exhibition on Science, Technology, and Engineering of Materials**, Patthaya, December 1st-2nd. and Material Today: Proceeding.