骨螺钉激光改性表面成骨细胞生长调控研究

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摘要：骨折是骨骼肌肉运动系统的常见损伤，我国老龄化群体骨质强度下降、体育运动、交通事故导致骨折发生率均逐年增加。骨螺钉是常见的骨折固定器械，现有骨螺钉存在易松动问题，可导致骨折固定系统失效，其在治疗过程中的紧固稳定性直接影响着恢复效果。多项研究表明，材料表面跨尺度微结构可促进骨细胞的附着力及分化生长，能显著提升组织与材料之间的附着力。针对现有骨螺钉抗松动性不足的问题，研究提出采用飞秒激光直写技术实现TC4钛合金骨螺钉螺纹表面微米-纳米多维跨尺度微结构的制造，提升骨螺钉的紧固可靠性。研究利用不同能流密度飞秒激光在骨螺钉表面诱导了周期性条纹-纳米颗粒、微米乳突-纳米颗粒和微米山脊-纳米凸起三种不同多维跨尺度微结构。采用扫描电镜表征了多维跨尺度微结构表面形貌；通过小鼠成骨细胞培养实验进行了骨细胞生长诱导特性及细胞毒性的评估。研究表明，在0.1J/㎜^{2}能流密度下会诱导出明显的周期性条纹结构和微驼峰结构，在0.4J/㎜^{2}能流密度下会诱导出微米条纹-纳米颗粒结构，在0.7 J/㎜^{2} 能流密度下诱导出微米山脊-纳米颗粒微结构，体外细胞实验表明0.7 J/㎜^{2} 能流密度诱导出的微米山脊-纳米颗粒微结构具有最佳的小鼠成骨细胞生长诱导性能，且细胞毒性与原始表面差别不大。本研究为高紧固可靠性骨螺钉制造提供了参考。

关键词：飞秒激光；骨螺钉表面改性；细胞生长

Abstract： Fractures are common injuries of the skeletal muscle motor system and the bone screws are common fracture fixation instruments. However, bone screw loosening can easily lead to the failure of fracture fixation system, and its tightening stability during treatment directly affects the recovery effect. Studies have shown that the cross-scale microstructure on material surface can promote the adhesion and differentiation growth of bone cells, significantly improve the adhesion between tissue and material. Therefore, we propose to use femtosecond laser direct writing technology to realize the fabrication of micro-nano multi-dimensional cross-scale microstructures on the surface of TC4 titanium alloy bone screw threads and increasing the reliability of fastening screw. In this study, three different multi-dimensional cross-scale microstructures of periodic stripe-nanoparticles, micron mastoid-nanoparticles and micro-ridge-nanoprotrusions were induced on the surface of bone screws by femtosecond laser with different energy density. The surface morphology of multi-dimensional cross-scale microstructure was characterized by scanning electron microscopy. The growth induction characteristics and cytotoxicity of osteocytes were evaluated by mouse osteoblast culture experiments. Studies have shown that obvious periodic stripe structure and micro-hump structure are induced at 0.1 J/mm^2 energy flow density, micro-stripe-nanoparticle structure is induced at 0.4 J/mm^2 energy flow density, and micro-ridge-nanoparticle microstructure is induced at 0.7 J/mm^2 energy flow density. In vitro cell experiments show that the micro-ridge-nanoparticle microstructure induced by 0.7 J/mm^2 energy flow density has the best mouse osteoblast growth induction performance, and the cytotoxicity is not much different from the original surface. This study provides a reference for the manufacture of high-reliability bone screws.

Keywords: femtosecond laser; Bone screws; Surface modification; Cell growth

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