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Titanium alloy mini-implants for orthodontic anchorage: Immediate loading and metal ion release ☆

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Abstract

Removable osseointegrated titanium mini-implants were successfully used as anchorage devices in orthodontics. The early load is necessary to simplify the mini-implant methodology, but can lead to failure during osseointegration. The Ti–6Al–4V alloy was used instead of commercially pure Ti due to its superior strength. However, the corrosion resistance is low, allowing for metal ion release. The purpose of this work was to analyze the immediately loaded mini-implant fixation and to gauge the vanadium ion release during the healing process. Titanium alloy mini-implants were inserted in the tibiae of rabbits. After 1, 4 and 12 weeks, they were submitted to removal torque testing. There was no increase in the removal torque value between 1 and 4 weeks of healing, regardless of the load. Nevertheless, after 12 weeks, a significant improvement was observed in both groups, with the highest removal torque value for the unloaded group. The kidney, liver and lung were also extracted and analyzed by atomic absorption spectrometry. In comparison with the control values, the content of vanadium increased slightly after 1 week, significantly increased after 4 weeks and decreased slightly after 12 weeks, without reaching the 1 week values. A stress analysis was carried out which enables both the prediction of the torque at which commercially pure (CP) Ti and Ti–6Al–4V deform plastically and the shear strength of the interface. This analysis reveals that the removal torques for CP Ti dangerously approach the yield stress. The results of this rabbit model study indicate that titanium alloy mini-implants can be loaded immediately with no compromise in their stability. The detected concentration of vanadium did not reach toxic levels in the animal model.

Keywords: Titanium alloy; Mini-implant; Orthodontic anchorage; Ion release

1. Introduction

Anchorage has long been a challenge since the introduction of fixed appliances in orthodontics [1]. Typically, orthodontic movement of a tooth is anchored by a large group of teeth so as to minimize undesired displacements of anchoring teeth. Adequate anchorage becomes difficult when posterior teeth are missing. Intra- and extra-oral auxiliary devices can be used to assist movement, but the effectiveness of these measures is dependent upon the level of patient cooperation [1].

Conventional titanium implants have emerged as an excellent alternative to traditional orthodontic anchorage methodologies, mainly when anchorage dental elements are insufficient in quantity or quality [2]. Unfortunately, conventional dental implants can only be placed in limited sites, such as the retromolar and edentulous areas [2,3]. In

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addition, conventional dental implants are troublesome for patients because of the severity of the surgery, the discomfort of the initial healing and the difficulty of maintaining oral hygiene [4].

Due to these disadvantages, Kanomi [5] proposed titanium mini-implants (1.2 mm in diameter and 6.0 mm in length) for orthodontic anchorage. They are widely used since they have few implantation site limitations, a simple insertion procedure and easy mechanical force control [6]. The methodology for implementation of mini-implants has been continuously improved. Some complications persist, and the sources of failure include the inflammation of the soft tissue around the mini-implant and fracture of the mini-implant [6].

A period of healing is usually necessary before applying load to conventional dental implants. This period varies from 4 to 6 months in humans [7,8]. When the load is placed prematurely, histological analyses have suggested that there is no uniform intimate bone-implant contact due to interplayed fibrous tissue [9,10]. This phenomenon could be favorable for implants for orthodontic anchorage purposes, since it facilitates the surgical removal of the implant at the end of the orthodontic treatment. On the other hand, the excess of interplayed fibrous tissue could lead to implant failure.

Commercially pure titanium (CP Ti) is widely used as implant material because of its suitable mechanical properties and excellent biocompatibility [11,12]. However, CP Ti has lower fatigue strength than titanium alloys. Ti–6Al–4V can be used to overcome this disadvantage [12,13]. However, the corrosion resistance of the mini-implant decreases when the alloy is used, favoring metal ion release, which has been associated with clinical implant failure, osteolysis, cutaneous allergic reactions, remote site accumulation [14], kidney lesion [15], cytotoxicity, hypersensitivity and carcinogenesis [16].

The purpose of this work was to measure the bone anchorage of immediately loaded Ti–6Al–4V mini-implants by removal torque test, and the amount of vanadium ion release in remote tissues by atomic absorption spectrometry.

2. Experimental

2.1. Materials

Seventy-two Ti–6Al–4V alloy mini-implants (Conexão Sistemas de Próteses, SP, Brazil) were used. The mini-implants had a cylindrical screw design, were 2.0 mm in diameter and 6.0 mm in length, and had a hexagonal-shaped head that was 3.4 mm in length. The mini-implants were machined by turning, cleaned, passivated with nitric acid (HNO_3) and sterilized. No surface treatment was applied to alter the roughness (Fig. 1). Ni–Ti closed coil springs were used as loading devices for half of the mini-implants.

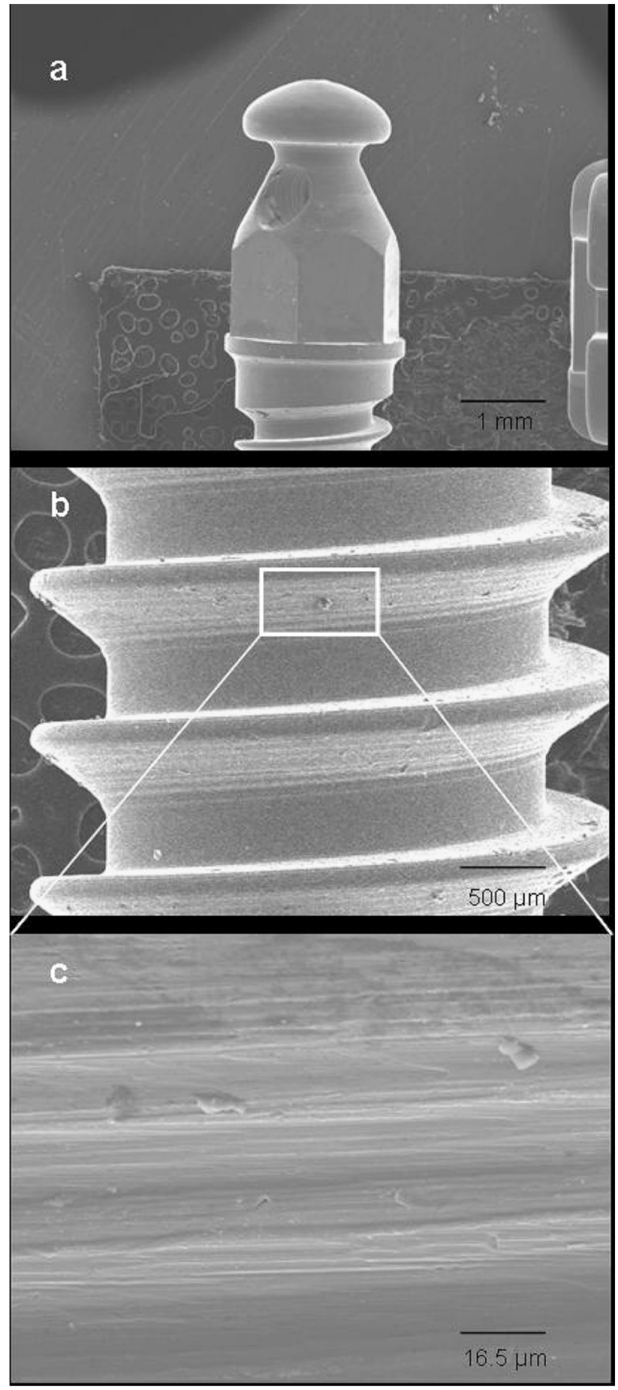

Fig. 1. Titanium alloy mini-implant: (a) hexagonally shaped head; (b) cylindrical screw design; (c) as-machined surface.

2.2. Animals

Twenty-three 6-month-old male New Zealand white rabbits, weighing between 3.0 and 3.5 kg, were used in the research. The surgical procedures exercised were common to the 18 experimental animals and consisted of the implantation of four mini-implants into the left tibial metaphyses of each animal. All surgeries were performed under sterile conditions in a veterinary operating room.