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ORIGINAL ARTICLE

Evaluation of mechanical strengths of three types of mini-implants in artificial bones

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Resonance frequency

Abstract We investigates the effect of the anchor area on the mechanical strengths of infrazygomatic mini-implants. Thirty mini-implants were divided into three types based on the material and shape: Type A (titanium alloy, 2.0×12 mm), Type B (stainless steel, 2.0×12 mm), and Type C (titanium alloy, 2.0×11 mm).The mini-implants were inserted at 90° and 45° into the artificial bone to a depth of 7 mm, without predrilling. The mechanical strengths [insertion torque (IT), resonance frequency (RF), and removal torque (RT)] and the anchor area were measured. We hypothesized that no correlation exists among the mechanical forces of each brand. In the 90° tests, the IT, RF, and RT of Type C (8.5 N cm, 10.2 kHz, and 6.1 N cm, respectively) were significantly higher than those of Type A (5.0 N cm, 7.7 kHz, and 4.7 N cm, respectively). In the 45° test, the RFs of Type C (9.2 kHz) was significantly higher than those of Type A (7.0 kHz) and Type B (6.7 kHz). The anchor area of the mini-implants was in the order of Type C (706 mm^2) > Type B (648 mm^2) > Type A (621 mm^2). Type C exhibited no significant correlation in intragroup comparisons, and the hypothesis was accepted. In the 90° and 45° tests, Type C exhibited the largest anchor area and the highest mechanical strengths (IT, RF, and RT) among the three types of mini-implants. The anchor area plays a crucial role in the mechanical strength of mini-implants.

Conflicts of interest: All authors declare no conflicts of interest.

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Introduction

Studies investigating the stability of mini-implants have focused on measures of mechanical strength, including insertion torque (IT) [1,2], removal torque (RT) [3], and pullout strength [4–6]. The procedures used to analyze these measures are nonrepeated, invasive, and destructive. Resonance frequency (RF) analysis is noninvasive, nondestructive, and objective, and can be applied repeatedly and continuously. Resonance is a phenomenon in which a continuous external force drives the oscillation of a vibrating system. For example, when an external force exhibits a periodic function with a frequency approximately equal to the natural frequency (or a specific preferential frequency) of a vibrating system, the vibration amplitude of the system increases rapidly to its maximum and then decreases suddenly after the frequency is reached. The frequency at which the amplitude of the vibrating system is the maximum is referred to as RF. Thus, providing a force that excites external frequencies for measurement of the RF of an implant can indicate the stiffness of the implant and surrounding bone, which is a measure of osseointegration.

Meredith et al. [7] revealed that a high RF indicates high stiffness. RF analysis of dental implants revealed a close correlation between *in vivo* and *in vitro* findings. Measuring the stiffness of dental implants and surrounding bone, which indicates the stability of the implants, can help clinicians to effectively diagnose and evaluate the osseointegration of dental implants and determine the time of dental implant loading, thereby ensuring the success of dental implants. Therefore, RF analysis can also be applied to assess the stability of orthodontic mini-implants to reduce the risk of failure.

When an infrazygomatic mini-implant is inserted, the corresponding soft tissue thickness at the insertion position must be considered. The available implant length of the infrazygomatic crest influences the primary stability of the mini-implant. Moreover, the thread design of a mini-implant considerably affects primary stability. The anchor area of the mini-implant may also contribute to primary stability but has never been studied. Therefore, this study investigated the relationship between the anchor area and mechanical strengths (IT, RF, RT) by using mini-implants with different designs.

Methods

In this study, we used 30 mini-implants of three brands commonly used by Taiwanese orthodontists to evaluate the effects of their design characteristics on the mechanical properties of artificial bone. The mini-implants were made of titanium alloy and stainless steel. These mini-implants were divided into three types based on the material and shape: Type A (titanium alloy, 2×12 mm), Type B (stainless steel, 2×12 mm), and Type C (titanium alloy, 2×11 mm). The mechanical strengths of the three types were measured in 90° and 45° (Figure 1). Moreover, the anchor area of the mini-implants was measured using a planimeter (X-PLAN 460dIII; Ushikata, Japan) (Figure 2). The anchor area measurement was according to the method of Aydemir et al. [8]. Both 90° and 45° tests could include and interpret the degrees of insertion of the clinical condition.

Figure 1. The mini-implants were inserted at 90° and 45°.

Each mini-implant was weighted using analytical balances (AS 220/C1; Radwag, Radom, Poland). The dimensions and shapes of the mini-implants were measured using scanning electron microscopy (SU8010; Hitachi, Tokyo, Japan) (Figures 3 and 4). The infrazygomatic crest was simulated with artificial bones (Sawbone; Pacific Research Laboratories, WA, USA), where a 2-mm cortical bone (40 pcf) was used as the cortical bone, whereas bone marrow (20-pcf cellular foam) was used as the medullary bone. According to anatomic consideration, five mini-implants of each brand were inserted to a depth of 7 mm in the 90° and 45° tests. All mini-implants were manually inserted into Sawbone without pilot drilling. A digital torque meter (Lutron, Taipei, Taiwan) was used to measure IT and RT. The degree of primary stability was tested using an RF analyzer (Implomate; BioTech One, Inc., Taipei, Taiwan) following the impulse force method (Figure 5).

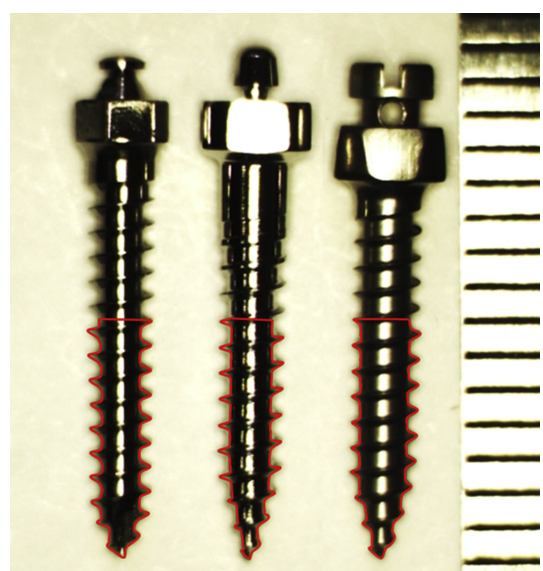

Figure 2. The mini-implants manufactured with three designed types, from left to right: Type A (2.0×12 mm), Type B (2.0×12 mm), and Type C (2.0×11 mm). Red line area: anchor area in the insertion 7 mm depth.