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Original Article

Effects of gripping volume in the mechanical strengths of orthodontic mini-implant

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Abstract The objective of study was to investigate the correlation between the mechanical strengths [insertion torque (IT); resonance frequency (RF); and horizontal pullout strength (HPS)] and gripping volume (GV) of mini-implants. Thirty mini-implants of three types (Type A: 2 mm × 10 mm, cylindrical, titanium alloy; Type B: 2 mm × 10 mm, tapered, stainless steel; and Type C: 2 mm × 11 mm, cylindrical, titanium alloy) were inserted 7 mm into artificial bones. One-way analysis of variance and Spearman's test were applied to assess intergroup comparisons and intragroup correlations. The null hypothesis was that no statistically significant correlations exist between the GV and mechanical strengths (IT, RF, and HPS). In the IT test, Type C (14.2 Ncm) had significantly ($p = 0.016$) greater values than did Type A (12.4 Ncm). In the RF analysis, no significant difference was observed among the three types of mini-implants. In the HPS test, Type C (388.9 Ncm) was significantly larger than both Type B (294.5 Ncm) and Type A (286 Ncm). In the GV measurement, Type C (14.4 mm^3) was significantly larger than Type B (11.4 mm^3) and Type A (9.2 mm^3). Type A and Type B exhibited no significant correlations among the tests. Therefore, the null hypothesis was accepted.

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

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Although no significant correlation was noted between the GV and mechanical strengths (IT, RF, and HPS), we observed a trend that the mechanical strengths (IT, RF, and HPS) of the mini-implants corresponded to the order and values of GV (Type C > Type B > Type A).

Introduction

Because of their reliable and stable anchorage, the use of mini-implants for the application of orthodontic force to control the various movements of teeth has become a trend. Mini-implants provide sufficient retention force for anchorage treatment and can be loaded with force immediately or within 2–3 weeks after they are implanted. However, traditional dental implants require at least 4 months for osseointegration. Therefore, primary stability is critical to the design of mini-implants. A review of the literature [1–3] indicated that mini-implants can achieve a success ratio of > 80%.

To date, studies have examined mini-implant stability, including the insertion torque (IT) [4,5], removal torque [6,7], and vertical and horizontal pullout strength (HPS) [8–10]. Because of immediate loading, the stability of a mini-implant relies on the mechanical interlocking between the mini-implant thread and the surrounding bones. Thus, the design of the thread affects resistance strength, which in turn has an impact on the primary stability of the mini-implant. Resonance frequency (RF) analysis [11,12] measures implant stability on the basis of the vibrations generated by the implants within the bones. RF analysis has been successfully applied to investigate the stability of conventional dental implants. Gripping volume (GV) is the bone volume gripped by the mini-implant. Therefore, the clinical relevance and significance of the GV implicate the primary stability of the mini-implant, which thus leads to resistance to the horizontal force during orthodontic treatment. However, no report has described the GV of mini-implants and its relation to mechanical strength.

In the present study, we conducted intergroup comparisons among three different brands of mini-implants, with a null hypothesis that no statistically significant intergroup correlation exists between the GV and mechanical forces (IT, RF, and HPS) of the mini-implants.

Materials and methods

In the present study, 30 mini-implants of three types were assessed: Type A (2 mm × 10 mm, cylindrical, titanium alloy), Type B (2 mm × 10 mm, tapered, stainless steel), and Type C (2 mm × 11 mm, cylindrical, titanium alloy). The features of the thread were investigated using a scanning electron microscope (Hitachi SU8010; Tokyo, Japan) [13]. In consideration of the mandibular buccal shelf region, the artificial bone (Sawbones, Pacific Research Laboratories, Inc., Vashon Island, WA, USA) comprised 3 mm of cortical bone (40 pcf) and bone marrow (20 pcf). Five mini-implants of each type were investigated in the mechanical strength test (IT, RF, and HPS). Moreover, five mini-implants of each type were assessed in the GV test.

The IT values were determined using a torque meter (Lutron Electronic Enterprise Co., Ltd., Taipei, Taiwan). All mini-implants were manually inserted 7 mm into Sawbone without pilot drilling. An RF analyzer (Implomates, BioTech One, Inc., Taipei, Taiwan) used the impulse force method to measure the RF intensity of each mini-plant [13]. The HPS test was performed using an orthodontic wire (0.018 in.) that was passed through the hole of the mini-implant and tied to a pulling material testing system (GOTECH AI-3000; Taichung, Taiwan). The GV test (Figure 1) used a Sawbone block (20 pcf) without cortical bone. All the mini-implants were weighed using analytical balances (Radwag AS 220/C1; Radom, Poland) before the GV test. The insertion procedure for the GV test was similar to the mechanical test except for the vertical pullout. The total mass (comprising the GV mass and mini-implant mass) was measured, and the GV mass was then calculated by subtracting the weight of the mini-implant. According to manufacturer's data sheets, the density of Sawbone (20 pcf) was 0.32 g/cm^3, and the GV was calculated through mass-density conversion.

SPSS software (IBM Corporation, Armonk, NY, USA) was used for statistical analysis in this study. All p values < 0.05 were considered statistically significant. One-way analysis of variance with a Tukey honest significant difference *post hoc* comparison was applied for intergroup comparisons. Spearman's rho correlation coefficient was used to examine intragroup relationships. The null hypothesis was that no statistically significant correlation exists between the GV and mini-implant mechanical forces in the intragroup comparisons.

Results

For each mini-implant, the dimensions of the upper third portion, which engaged with the cortical bone, are shown in Table 1. Among the inner diameter measurements, Type C (1.55 mm) had the highest value and Type B (1.43 mm) the lowest. Type B had the greatest thread depth (0.34 mm) and the lowest inner/outer diameter ratio (0.68). The pitch of Type A was the lowest (0.67 mm). Regarding the measurements of thread angles, Type A had the greatest apical face angle (43°) and flank angle (63°).

The mechanical strengths (Figure 2) and GVs of the mini-implants are shown in Table 2. In the IT test, Type A (12.4 Ncm) had significantly ($p = 0.016$) lower values than did Type C (14.2 Ncm). In the RF analysis, no significant difference was observed among the three types of mini-implants. In terms of GV measurements, Type C (14.4 mm^3) was significantly larger than Type A (9.2 mm^3) and Type B (11.4 mm^3). In the HPS test, Type C (388.9 Ncm) was significantly larger than Type A (286 Ncm) and Type B (294.5 Ncm). The results of intergroup comparisons (IT,