Comparison of the Mechanical Properties of 2 Prosthetic Mini-implants

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Generally, 3 to 6 months are needed to establish osseointegration of an implant. During the treatment, prosthetic mini-implants can be transitionally applied to prevent overloading the main implants and to improve the quality of life for patients by maintaining masticatory function. Recently, mini-implants have been widely used for various purposes: reinforcement of the dental arch against occlusal force during the healing period of the main fixtures,[1-6] to anchor the removable dentures,[7,8] orthodontic anchorages,[9,10] periodontal therapy,[11,12] and temporary fixation anchorage of the transplanted teeth[13]. Although there are some problems, including loosening,[3,11,14] deformations,[15] and fracture of the implants,[3,11,14] there are few reports on the basic mechanical properties of prosthetic mini-implants. This study measured the mechanical and physical properties of 2 prosthetic mini-implants with very similar shapes.

Two prosthetic mini-implants (MTI and MDI), which have very similar shapes, are widely used. In this investigation, the mechanical and physical properties of 2 prosthetic mini-implants were investigated. The flexural properties were measured with a universal testing machine. The surface image was observed by SEM with EDX. X-ray analyses were performed. The maximum strength and proportion limit for the different implants differed significantly (P <0.01); however, elastic modulus did not differ significantly (P >0.01). Although the surface of the MTI was smooth, the MDI had a rough surface. The elemental analysis detected titanium (Ti) in the MTI, and Ti, aluminum, and vanadium in the MDI. From the x-ray diffraction pattern, the MTI, which is composed of pure titanium, had a narrow, sharp Ti (syn) peak, whereas the corresponding peak for the MDI was small and broad. Although the 2 devices have similar shapes and dimensions, their surfaces and mechanical properties differ greatly. MTI is easy to remove and wrought in clinical use, and MDI is excellent in flexural properties compared with MTI. (Implant Dent 2004;13:251–256)

Key Words: mini-implant, flexural property, x-ray analysis, elemental analysis

Materials and Methods

Description of Mini-implants

The 2 prosthetic mini-implants used in the flexural tests, a Mini-Transitional Implant (MTI; 21 × .8 mm; Dentatus USA, New York, NY) and a Mini Dental Implant (MDI; 22 × .8 mm; IMTEC, Ardmore, OK), are shown in Figure 1. The screw for the MTI is cut 7.5 mm from the tip, and that of the MDI is cut at 4.7 mm.

Flexural Test. Without modification, the prosthetic mini-implants were horizontally fixed to a holder 7.5 mm from the tip and a perpendicular load was added 4 mm from the tip (Fig. 2). A universal testing machine (TG-50 kN; Minebea, Nagano, Japan) was used for the flexural test with a test speed of 2 mm/min. The maximum strength (M) and proportion limit (P) were obtained from the load–strain curves, and the elastic modulus (E) was calculated from the slope of the tangent (Fig. 3). Five measurements were made and the data were analyzed statistically using the Mann-Whitney *U* test.

SEM Observation. The surface of the prosthetic mini-implant was observed by FE-SEM (S-4200, acceleration voltage 20 kV; Hitachi, Tokyo, Japan), and simultaneous elemental analysis (EDX + Oxford LINK ISIS) of the surface was performed.

X-ray Diffraction Analysis. Five prosthetic mini-implants were fixed in a specimen holder and subjected to x-ray diffraction (Rint 2000; Rigaku, Tokyo, Japan). The diffraction conditions were CuKα, 40 kV, 30 mA, at a scanning rate of 2°/min.

Results

Flexural Test

The value of M was 68.6 ± 6.1 and 160.1 ± 25.2 N for the MTI and MDI, respectively, and P was 21.7 ± 3.5 and 87.3 ± 26.5 N (Fig. 4A, B). The values of M and P for the different implants differed significantly (P <0.01). E was 151.4 ± 20.2 and 156.9 ± 20.4 N/mm, respectively, and did not differ significantly (P >0.01) (Fig. 4C). This means that ductility of MTI is generated by lower stress

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ISSN 1056-6163/04/01303-251
Implant Dentistry
Volume 13 • Number 3

DOI: 10.1097/01.id.0000136912.98138.c3

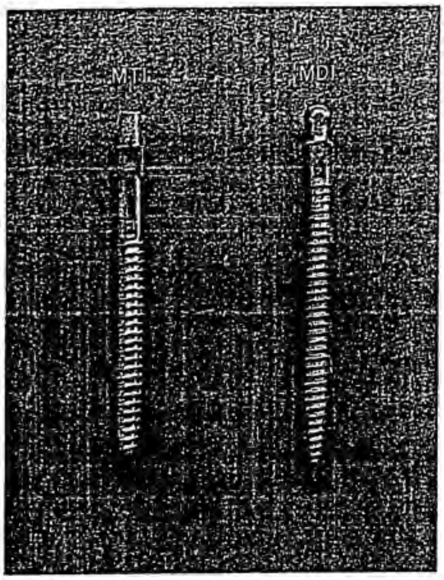

Fig. 1. The 2 prosthetic mini-implants used in this investigation (left, MTI; right, MDI).

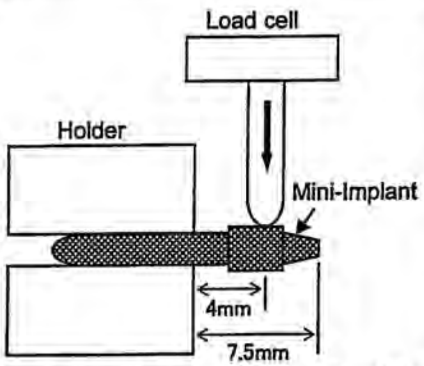

Fig. 2. The schematic representation of the flexural test. The prosthetic mini-implants were horizontally fixed to a holder 7.5 mm from the tip and a perpendicular load was added 4 mm from the tip.

than MDI and that, in proportional limits, MTI and MDI would show the similar distortion with a stress and the similar recovery in the removal of a stress.

SEM Observation

SEM images of the MTI and MDI are shown in Fig. 5. The surface of the MTI is smooth, although there are a few streaks caused by machining. The MDI has a rough surface as a result of etching. The elemental analysis detected titanium (Ti) in the MTI, and Ti, aluminum (Al), and vanadium (V) in the MDI (Fig. 6). This means that the difference between the surfaces of MTI and MDI would affect the re-

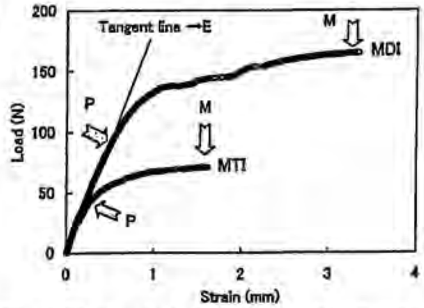

Fig. 3. The load–strain curves and each measuring points. The maximum strength (M) and proportion limit (P) were obtained from the load–strain curves, and the elastic modulus (E) was calculated from the slope of the tangent line.

moval and the osseointegration of mini-implants.

X-ray Diffraction Analysis

The x-ray diffraction pattern is shown in Fig. 7. The open circle (O) corresponds to the Ti (syn) peak. The MTI, which is composed of pure titanium, had a narrow, sharp Ti (syn) peak, whereas the corresponding peak for the MDI was small and broad. This means that both prosthetic mini-implants are composed of the α phase of Ti at room temperature.

Discussion

Prosthetic mini-implants are applied during implant treatment to prevent overloading of the main implants and to maintain masticatory function. The prosthetic mini-implants are installed adjacent to the main implants and are used to support a temporary prosthesis. After final treatment, they are removed. The use of prosthetic mini-implants not only helps success of the main implant treatment, but also improves the quality of life for the patient during treatment. The prosthetic mini-implants are as small as 1.8 mm in diameter and are installed with or without incision. There is no statistical report of the relationship between the incision and nonincision. Furthermore, prosthetic mini-implants can be used in the alveolar ridge that has marked buccolingual absorption and can also be used in the narrow spaces of the interdental papillae. Consequently, there has been a recent increase in the use of transitional implants[1-6] for anchorage of removable dentures,[7,8] as anchors in orthodontic

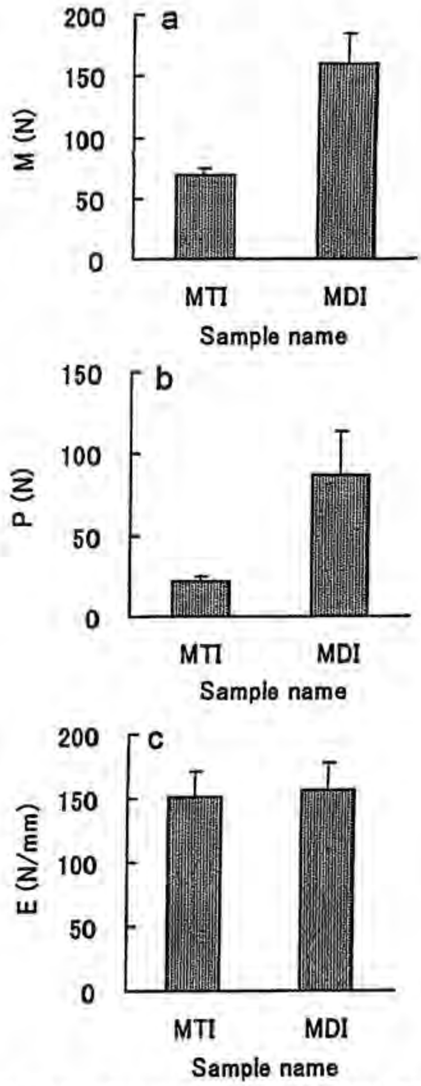

Fig. 4. The flexural properties of the MTI and MDI (A, the maximum strength [M]; B, the proportion limit [P]; C, the elastic modulus [E]). The M and P values of MDI significantly increased compared with that of MTI (P <0.01), and the P values of both mini-implants did not differ significantly (P >0.01).

treatment,[9,10] in the preservation of highly advanced periodontitis-affected teeth,[11,12] and in the postoperative fixation of transplanted teeth.[13].

There are some problems with prosthetic mini-implants. These include their loosening, deformation, and fracture during treatment and at removal because their diameters are so small. When prosthetic mini-implants fracture, it is necessary to remove a wide area that includes circumferential bony tissue. When an implant is malleable, deformation and fracture could occur easily. On this point, Nagata et al.[11] reported that a mini-implant frac-

Fig. 5. SEM images of screwed surface of the MTI (left) and MDI (right). The MTI has a smooth surface with a few streaks and the MDI has a rough surface.

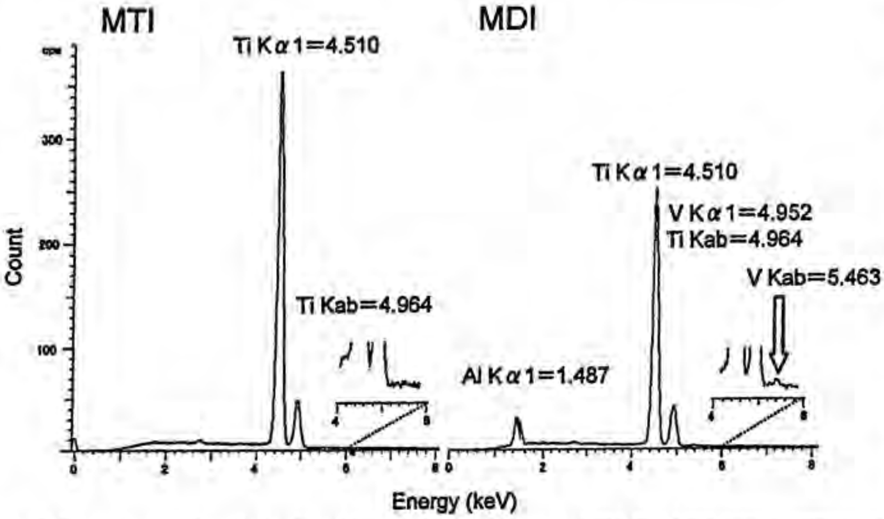

Fig. 6. The elemental analysis of the MTI and MDI surfaces by EDX. The MDI detected titanium (Ti), and the MDI detected Ti, slight aluminum (Al), and slight vanadium (V).

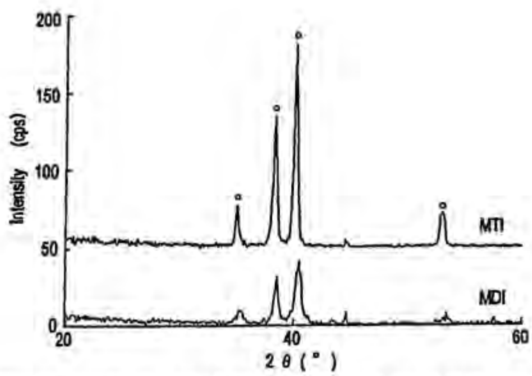

Fig. 7. The x-ray diffraction pattern of the MTI and MDI. The open circle (O) corresponds to the α phase of titanium at room temperature.

ture was recorded in 1 of 85 cases. Prostheses can be easily fabricated by bending the upper part of this type of prosthetic mini-implant (MTI) in a planned direction. Simultaneously, this malleability of the metal means that deformation or fracture can also occur easily at removal. To examine deformation or fracture at removal, Simon et al.[15] measured the torque while removing prosthetic mini-implants and reported that breakage occurred at 30 Ncm.

Nagata et al.[11] also reported the loosening of 13 (15.3%) of 85 prosthetic mini-implants during treatment. Loosening during treatment was closely related to the quality and quantity of the bone, osseointegration, the structure of the temporary prosthesis attached to the upper part of the prosthetic mini-implants, and the magnitude of the dynamic load. Although it is difficult to examine all these factors from our results, our measured values for the 2 implants indicate that a lateral force of 20 N will cause deformation of approximately 0.1 mm. Clinically, an implant cannot always be placed perfectly in the ideal location and with ideal orientation. In such a case, it is thought to be difficult to adjust the prosthesis without bending. On the other hand, parallel installation of the mini-implant can result in loss of mechanical strength, which is led by offset structure or random inclination. In addition, as the rigidity of the prosthetic mini-implant increases, more of the external force on the upper part of the implant transmits directly to the bone/implant interface. The force could be further intensified by the small diameter of the prosthetic mini-implants, so that when a strong external force is applied to the implant body before osseointegration, there is a high risk that the prosthetic mini-implants will loosen.

Therefore, when a mini-implant is used, during the healing period of the main implants, its characteristics should be known sufficiently. There has been 1 report[15] on their mechanical properties. The torque has been measured while removing prosthetic mini-implants. However, it is not a mechanical property in use. These should be the basis of clinical discussion.

In this study, we measured 2 different implants. According to the manufacturers' information, both implants are 1.8 mm in diameter. As a result, it was easy to compare the measured values of the materials directly. From measurements on intact implants, the force required to cause deformation in clinical use can be predicted. The value of P measured in this study corresponds to the stress of the proportional limit of the S-S curve. In oral application, the threshold stress that does not cause plastic deformation can be estimated. The value of P for the MDI is approximately 2.3 times that for the MTI; consequently, biting force has less of an effect on the MDI than on the MTI. It is also very difficult to bend the MDI, and this requires a larger force than for the MTI, making it difficult to correct the orientation of prosthetic mini-implants.

There was no significant difference in E for the 2 materials ($P > 0.05$). In the S-S curve, this value corresponds to the elastic modulus, and it indicates the level of flexibility when applying a force. The elastic deformation of the 2 materials was similar for a comparatively weak force (under approximately 20 N).

Titanium base alloys are classified as α, β, and $\alpha + \beta$ alloys according to their constituent phases at room temperature. Pure titanium is in the α phase at room temperature. Consequently, the x-ray diffraction peak of the MTI was for the α phase. Moreover, most of the MDI was in the α phase. Although pure titanium is not very strong, it can be strengthened by adding aluminum and vanadium. The elemental analysis showed peaks for aluminum and vanadium in the MDI. When aluminum is added to titanium, the region of the α phase expands and the strength at room temperature increases. As a result, the strength of the MDI was 2.3 times that of the MTI. Optimally, the aluminum content should be under 7 wt%. The MDI is reported to be 6 wt% aluminum and 4 wt% vanadium.[13]

The SEM images showed that the MTI had a smooth surface as a result of machine finishing, whereas the MDI had a rough surface as a result of etching. Generally, a rough surface is more advantageous for osseointegration. Both of these implants are often used as temporary implants and there are many clinical reports on them.[1-6] They basically differ because the MDI was originated as an anchor for semi-permanent attachment dentures. It is very rigid and difficult to deform or break during removal. By contrast, the MTI was developed as a temporary implant noted for its ease of removal.

Conclusion

Although 2 prosthetic mini-implants, MTI and MDI, have similar shapes and dimensions, their surfaces and mechanical properties differ greatly. The surface of the MTI is smooth, and the MDI has a rough surface. The MTI is extremely easy to use and very malleable but also weaker than the MDI, whereas the MDI is a high-intensity matrix strengthened by vanadium and aluminum. When ease of removal or of work ability of the mini-implant is required, then the MTI should be used; and if priority is given to the intensity, MDI should be chosen.

Disclosure

The authors claim to have no financial interest in any company or any of the products mentioned in this article.

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