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Review

Clinical indices for orthodontic mini-implants

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Abstract: Orthodontic mini-implants were recently developed and have been widely used in clinics. However, loosening of mini-implants, as well as infection and swelling of mucosal tissue at the placement site, are often observed during orthodontic treatment. Thus, clinical indices are greatly needed for the safe use of orthodontic mini-implants. This article presents information on mini-implants and offers suggestions on indications, placement technique, optimum design, and evaluation of the placement site for mini-implants. The author concludes that 1) mini-implants should be left in the placement site for 3 months before loading to allow for a healing period, which increases the success rate in adolescent patients, 2) placement torque should be considered when tightening mini-implants into bone, as excessively high or low torque results in low stability, 3) mini-implants with optimal screws should be placed in the correct position, and 4) a prepared site should be established in an area with a cortical bone thickness of greater than 1.0 mm, to improve the success rate. Finally, the vector of orthodontic forces in the arrangement with the center of resistance of the entire dental arch should be considered when developing treatment goals. (J Oral Sci 53, 407-412, 2011)

Keywords: miniscrew; temporary anchorage device; survival rate; implant anchor.

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Introduction

Areas of tooth movement and immobile areas that resist orthodontic forces are observed in orthodontic treatment. Proper orthodontic anchorage is necessary to ensure predictable tooth movement and prevent insufficient reciprocal movement.

In recent years, orthodontic mini-implants were developed to ensure complete orthodontic anchorage (1-7). Mini-implants reduce the burden on patients and help in attaining treatment goals; however, many patients develop complications such as loosening and deciduation of mini-implants, infection, pain and swelling around the placement site, and contact with and injury to proximal teeth roots (3,8-11). To avoid such complications, the risk factors for failure of mini-implants have been investigated (12-16). Studies indicate that the stability of mini-implants is related to bone quality and quantity, membrane condition, and screw diameter, length, and design. In addition to these factors, safe placement technique and placement site must be assessed.

To develop indices for safe, high-quality, orthodontic treatment when using mini-implants, the author reviews the literature on mini-implants and addresses the indications, safe placement technique, and optimal design and features of mini-implants, and the anatomical and mechanical evaluation of the placement site.

Indications

Mini-implants are frequently used in cases that require absolute anchorage, depression and/or distalization of molars. The age range for successful implantation is a matter of controversy. Mini-implants placed in alveolar bone are effective in adolescent patients, and marked improvement is often observed, even in patients with skeletal problems. However, mini-implants often loosen during orthodontic treatment, and this is often seen in teenagers (17). The author previously studied the success rate of mini-implants in adolescent patients (15). Among 57 orthodontic patients aged 11.7 to 36.1 years who underwent surgery for mini-implant insertion (169 implants), the success rate was 63.8% in an adolescent early-load group (healing period, < 1 month), 97.2% in an adolescent late-load group (healing period, 3 months), and 91.9% in an adult group. A healing period of three months before orthodontic loading resulted in a significant improvement in success rate (from 63% to 97%) for mini-implants in adolescents. This finding indicates that, to increase the success rate, orthodontic mini-implants should be left in situ for three months. In the clinic, mini-implants should be placed before starting orthodontic treatment in adolescent patients, to ensure a healing period of longer than three months (15).

Safe placement technique

Clinicians must observe basic surgical techniques to prevent infection. Instruments and materials such as handpieces, hand screwdrivers, bone twist drills, and titanium mini-implants should be sterilized before surgery. After disinfection of the placement site, infiltration anesthesia should be injected into a movable membrane. The surgical incision depends on the particular situation, as mucosal tissue can be caught in the bone twist drill. A pilot hole should be drilled before placement of a self-tapping type screw. A self-drilling screw can be inserted into the bone by using a hand screwdriver, without a pilot hole.

Meredith (18) found that hoop stresses, which are generated near dental implant threads, can be beneficial in enhancing the primary stability of the implant. However, such stress can reach a high level, resulting in necrosis and local ischemia of the bone at the implant–tissue interface, when the implant diameter is very large as compared with the implant hole. Friberg et al. (19) measured the cutting torque of a self-tapping dental implant and observed that most failures occurred in bone of medium-to-high density. The optimal stress for enhancing the stability of an implant is a value that is not very high or very low. Thus, using a torque screwdriver, the author measured the peak value of implant placement torque (IPT) so as to determine the adequate placement torque for improving the success rate for mini-implants that are screwed into the buccal alveolar bone of the posterior region (13). The implants were divided into three groups according to IPT: 5 Ncm or less, 5.1 to 10 Ncm, and more than 10 Ncm. The success rate was significantly higher in the 5.1 to 10 Ncm group than in the other two groups (13). Initial stability might not be obtained if the IPT is very low, and subsequent stability, which is supported by bone apposition surrounding the screw thread, might not be acquired if the IPT is very high. Very high placement torque can generate a high level of stress, resulting in degeneration of the bone at the implant–tissue interface (18) and aggravation of bone regeneration in the area surrounding the implant thread.

In a previous study, the author evaluated the placement and removal torques of mini-implants to identify factors that affect the long-term stability of mini-implants (20). Other researchers measured removal torque for mini-implants in animals or bone specimens (21-23). Kim et al. (24) measured removal torque for surface-treated mini-implants in humans. Removal torque reflects the characteristics of the implant–bone interface during and after long-term orthodontic treatment. Because removal torque is the resistance force required to remove a mini-implant after orthodontic treatment, it can be used to evaluate the anchorage capability of mini-implants. Removal torque is not affected by the degree of firmness when tightening mini-implants, because it is not significantly associated with placement torque (20). Okazaki et al. (23) investigated removal torque after mini-implants measuring 1.2 mm in diameter were placed in 1.0-mm and 1.2-mm cavities prepared in dog femurs. They found that removal torque values for the 1.2-mm cavities 6 weeks after placement were similar to those for the 1.0-mm cavities, whereas removal torques immediately after insertion were significantly lower for the 1.2-mm cavities than for the 1.0-mm cavities. A study by the present author confirmed that removal torque does not depend on placement torque in humans (20). Torque decreased from approximately 8 to 4 Ncm after clinical use. When subjects were divided into 3 torque groups, the torque in the low-torque group had a constant value of approximately 4 Ncm, whereas the values in the intermediate- and high-torque groups significantly decreased to approximately 4 Ncm. Immediately after placement, the implant–bone interface was affected by bone stiffness at the prepared site, screw design, and the size of the pilot hole relative to the diameter of the mini-implant (12-14). Several months after placement, the increased compressive stress on the bone surrounding the mini-implant can disappear with accompanying bone metabolism, thus reducing torque. All mini-implants in this study were subjected to a sustained orthodontic force of less than 4 Ncm, regardless of torque. Therefore, 4 Ncm might be sufficient torque for orthodontic anchorage. For successful implantation, a pilot drill might prevent overtorquing, thereby improving the success rate when tightening the mini-implant into stiff bone (13,14). When the prepared site is fragile and the placement torque is less than 4 Ncm, even with self-drilling without a pilot drill, a longer healing period might improve anchorage of mini-implants.

Optimal design and features of mini-implants

Due to the possibility of injury to proximal teeth roots, Deguchi et al. (16) recommended the use of screws less than 1.5 mm in diameter and shorter than 6 mm for placement on the buccal alveolar bone in the posterior region. Miyawaki et al. (12) suggested that screws with a diameter of 1.5 mm should be used in patients with thick cortical bone and that screws with a diameter of more than 2.3 mm should be used in patients with thin cortical bone. With regard to the design of the screw, Yano et al. (25) found that tapered screws can tolerate immediate-loading and achieve stable anchorage with a high rate of success, but that straight screws can be used for orthodontic anchorage if there is a sufficient healing period. To avoid root contact and to ensure stability after placement, the author recommends that regular screws (i.e., about 1.5 mm in diameter) should be used in a region with sufficient cortical bone thickness and bone quality; however, in a region with fragile bone, wide screws (i.e., 2 to 2.3 mm in diameter) are preferred. Screw length should be determined after considering placement location and the condition of mucosal tissue: regular screws (i.e., 6 to 8 mm in length) should be used in the upper and lower buccal alveolar bone and long screws (i.e., > 10 mm in length) should be used in a region with thick mucosal tissue, such as palatal alveolar bone. In any event, it is important to place the optimally designed screw in the correct position, in accordance with the instructions of the manufacturer and developer.

Anatomical evaluation of placement site

Miyawaki et al. (12) concluded that a high mandibular plane angle, which is often present in thin cortical bone, was associated with mini-implant failure. This finding indicates that bone thickness and screw diameter are related to the stability and loosening of mini-implants. The present author investigated the relationship between cortical bone thickness and the success rate of mini-implants placed in buccal alveolar bone of the posterior region (14). The findings indicated that to achieve successful implantation the prepared site should be established in an area with a cortical bone thickness of more than 1.0 mm. Next, we investigated cortical bone thickness in the buccal posterior region mesial and distal to the first molar, where mini-implants are often placed, and examined any differences with regard to location, age, and sex (26). Morphometric analysis revealed that the cortical bone of the mandible was significantly thicker than that of the maxilla at all locations in the buccal posterior region and that cortical bone in the maxilla mesial to the first molar was thinner in females than in males in the area of attached gingiva. The mandible suffices as a preparation site for mini-implants, although the maxilla might be inadequate at shallow locations. Regardless of age, the initial stability of mini-implants should be carefully assessed in the area of attached gingiva in the maxilla of women. In such cases, an inclined placement (i.e., with the mini-implant inclined 30° to 60° to the bone surface) effectively increases bone-to-implant contact.

Computed tomography (CT) yields instructive information. Recommended placement sites are the maxillary alveolar bone, buccal and palatal alveolar bone in the posterior region, labial anterior alveolar bone, and the median palatal region. In the mandible, labial and buccal alveolar bone are recommended. At any of the abovementioned positions, the area of keratinized membrane is endorsed to avoid infection, and anatomical arrangement—such as inter-root distance, maxillary sinus, and nervous canal—must be carefully considered before placement. CT examination of the dentofacial field improves the success rate and ensures safe placement.

Mechanical evaluation of the placement site

Mini-implants are frequently placed in upper buccal alveolar bone between the second bicuspid and first molar in bicuspid extraction cases. Sung et al. (27) simulated en-masse movement of the anterior segment using finite element analysis. They hypothesized the center of resistance (CR) of the anterior segment and measured distortion of the archwire and tipping movement of the anterior teeth. However, this simulation calculated initial behavior immediately after force application. Clinically, anterior and posterior teeth move and wire distortion would be cancelled over time when continuous, stiff archwire is used; the entire dental arch can be hypothesized as a massive structure. The present author then hypothesized the CR of the entire dental arch and attempted to simulate long-term behavior (28). In bicuspid extraction, movement of the entire upper dental arch can be vertically controlled by alteration of the orthodontic force vector. If we posit a condition in which the anterior and posterior segments are rigidly fixed by inserting a stiff archwire into the bracket slots, the CR of the entire dental arch can be approximated around the root of the bicuspid, as

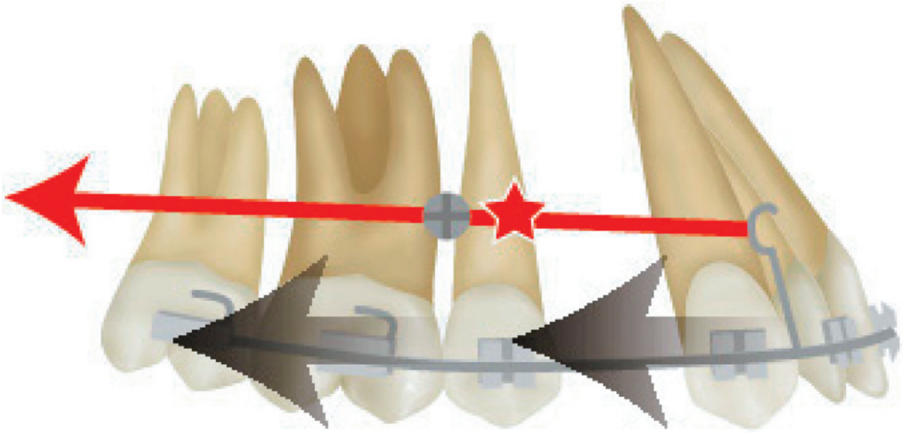

Fig. 1 Traction force and tooth movement. ★: Center of resistance (CR) of the dental arch. Red arrow: orthodontic traction force; Black arrows: direction of tooth movement. Parallel translation in the posterior direction is seen when the force vector is directed through the CR and remains parallel to the occlusal plane.

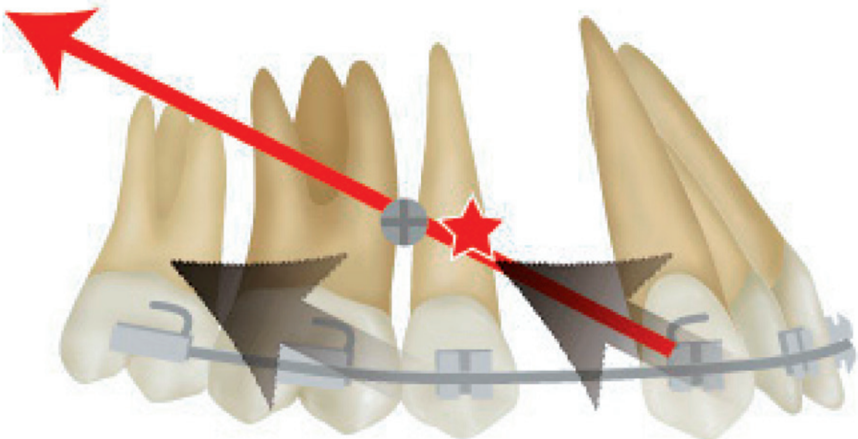

Fig. 2 Parallel translation in the posterosuperior direction is seen when the force vector passes through the CR and is directed in a posterosuperior direction.

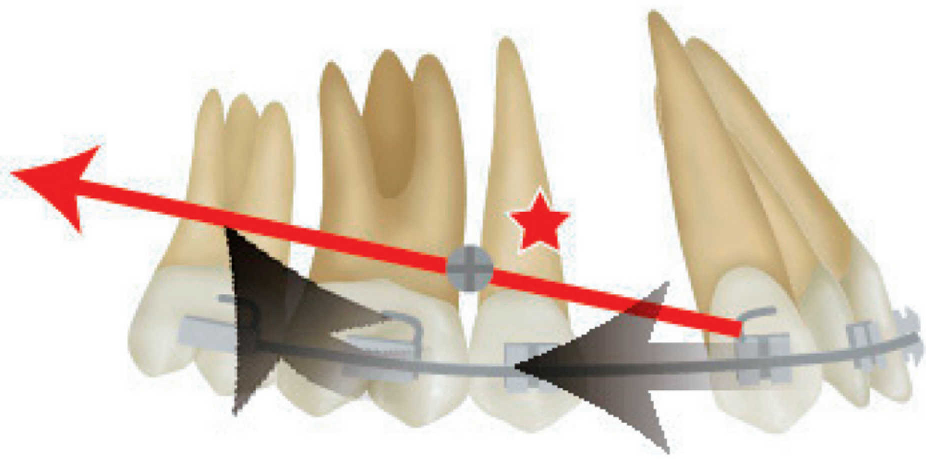

Fig. 3 Depression of molars and distal movement of the anterior teeth is expected when the force vector is directed inferior to the CR

shown in Figs. 1 to 3. When we intend to produce bodily movement of the anterior segment in patients with a mesiofacial pattern, the force vector should be parallel to the occlusal plane, as shown in Fig. 1. In patients with a dolicofacial pattern and excessive overbite, who require counterclockwise rotation of the mandible by depressing the entire maxillary dental arch, the force vector should be directed as shown in Fig. 2, so that it passes through the CR of the upper dental arch and the force is directed in a posterosuperior direction. In a patient with a dolicofacial pattern and anterior open bite who is expected to depress the posterior teeth, it is effective to direct the force vector to pass inferior to the CR, as shown in Fig. 3.

As indicated above, we can forecast the behavior of tooth movement by considering the vector of orthodontic force in an arrangement against the CR of the entire dental arch. Counterclockwise rotation of the maxillary dental arch is expected as the force vector passes superior to the CR, clockwise rotation is observed when the force vector passes inferior to the CR, and parallel translation is observed when the force vector passes through the CR. Movement of the molars in bicuspid extraction cases is vertical only, because forces in the distal direction loading on the molars from the mini-implants (arrows on molars in Fig. 1 to 3) would be counterbalanced by forces in the mesial direction, accompanied by the forces of en-masse movement. Therefore, the molars in Fig. 1 would remain vertically fixed, while the molars in Figs. 2 and 3 would show depressive movement.

References

1. Kanomi R (1997) Mini-implant for orthodontic anchorage. J Clin Orthod 31, 763-767.
2. Freudenthaler JW, Haas R, Bantleon HP (2001) Bicortical titanium screws for critical orthodontic anchorage in the mandible: a preliminary report on clinical applications. Clin Oral Implants Res 12, 358-363.
3. Sawa Y, Goto K, Suzuki N, Kamo N, Kamo K (2001) The new method for the maxillary retraction of the anterior teeth using a titanium microscrew as anchorage. Orthod Waves 60, 328-331. (in Japanese)
4. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH (2002) Clinical application of micro-implant anchorage. J Clin Orthod 36, 298-302.
5. Park HS, Kyung HM, Sung JH (2002) A simple method of molar uprighting with micro-implant anchorage. J Clin Orthod 36, 592-596.
6. Herman RJ, Currier GF, Miyake A (2006) Mini-implant anchorage for maxillary canine retraction: a pilot study. Am J Orthod Dentofacial Orthop 130, 228-235.
7. Kim TW, Kim H, Lee SJ (2006) Correction of deep overbite and gummy smile by using a mini-implant with a segmented wire in a growing Class II Division 2 patient. Am J Orthod Dentofacial Orthop 130, 676-685.
8. Costa A, Raffainl M, Melsen B (1998) Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg 13, 201-209.
9. Kadioglu O, Büyükyilmaz T, Zachrisson BU, Maino BG (2008) Contact damage to root surfaces of premolars touching miniscrews during orthodontic treatment. Am J Orthod Dentofacial Orthop 134, 353-360.
10. Cho UH, Yu W, Kyung HM (2010) Root contact during drilling for microimplant placement. Affect of surgery site and operator expertise. Angle Orthod 80, 130-136.
11. Kim SH, Kang SM, Choi YS, Kook YA, Chung KR, Huang JC (2010) Cone-beam computed tomography evaluation of mini-implants after placement: is root proximity a major risk factor for failure? Am J Orthod Dentofacial Orthop 138, 264-276.
12. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T (2003) Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 124, 373-378.
13. Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N (2006) Recommended placement torque when tightening an orthodontic mini-implant. Clin Oral Implants Res 17, 109-114.
14. Motoyoshi M, Yoshida T, Ono A, Shimizu N (2007) Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implant. Int J Oral Maxillofac Implants 22, 779-784.
15. Motoyoshi M, Matsuoka M, Shimizu N (2007) Application of orthodontic mini-implants in adolescents. Int J Oral Maxillofac Surg 36, 695-699.
16. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T (2006) Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop 129, 721.e7-12.
17. Park HS, Lee SK, Kwon OW (2005) Group distal

movement of teeth using microscrew implant anchorage. Angle Orthod 75, 602-609.
18. Meredith N (1998) Assessment of implant stability as a prognostic determinant. Int J Prosthodont 11, 491-501.
19. Friberg B, Sennerby L, Gröndahl K, Bergström C, Bäck T, Lekholm U (1999) On cutting torque measurements during implant placement: a 3-year clinical prospective study. Clin Implant Dent Relat Res 1, 75-83.
20. Motoyoshi M, Uemura M, Ono A, Okazaki K, Shigeeda T, Shimizu N (2010) Factors affecting the long-term stability of orthodontic mini-implants. Am J Orthod Dentofacial Orthop 137, 588.e1-5
21. Wilmes B, Rademacher C, Olthoff G, Drescher D (2006) Parameters affecting primary stability of orthodontic mini-implants. J Orofac Orthop 67, 162-174.
22. Song YY, Cha JY, Hwang CJ (2007) Mechanical characteristics of various orthodontic mini-screws in relation to artificial cortical bone thickness. Angle Orthod 77, 979-985.
23. Okazaki J, Komasa Y, Sakai D, Kamada A, Ikeo T, Toda I, Suwa F, Inoue M, Etoh T (2008) A torque removal study on the primary stability of orthodontic titanium screw mini-implants in the cortical bone of dog femurs. Int J Oral Maxillofac Surg 37, 647-650.
24. Kim SH, Cho JH, Chung KR, Kook YA, Nelson G (2008) Removal torque values of surface-treated mini-implants after loading. Am J Orthod Dentofacial Orthop 134, 36-43.
25. Yano S, Motoyoshi M, Uemura M, Ono A, Shimizu N (2006) Tapered orthodontic miniscrews induce bone-screw cohesion following immediate loading. Euro J Orthod 28, 541-546.
26. Ono A, Motoyoshi M, Shimizu N (2008) Cortical bone thickness in the buccal posterior region for orthodontic mini-implants. Int J Oral Maxillofac Surg 37, 334-340.
27. Sung SJ, Jang GW, Chun YS, Moon YS (2010) Effective en-masse retraction design with orthodontic mini-implant anchorage: a finite element analysis. Am J Orthod Dentofacial Orthop 137, 648-657.
28. Motoyoshi M, Shimizu N (2006) Orthodontic treatment using TAD: temporary anchorage devices; placement technique and clinical applications. Quintessence, Tokyo, 37-44. (in Japanese)