Five-year experience with orthodontic miniscrew implants: A retrospective investigation of factors influencing success rates

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Introduction: Anchorage control is important for efficient orthodontic treatment with fixed appliances. Successful osseointegration encouraged many orthodontists to use dental implants as stationary anchorage units for force application. However, their use has some drawbacks, which led to the development of miniscrew implants (MIs). Our aim was to investigate factors significantly contributing to the success rates of MIs in various orthodontic treatment procedures in white patients.

Methods: In total, 350 self-tapping (187 Abso Anchor [Dentos, Daegu, South Korea] and 163 Ortho Easy Pin [Forestadent, Pforzheim, Germany]) MIs used to reinforce orthodontic anchorage and placed in 130 consecutively chosen patients were assessed retrospectively. Clinical variables possibly influencing the success rates of MIs were categorized into patient-related, implant-related, location-related, and orthodontic-related. Statistical evaluation included descriptive statistics and survival analysis. The survival curves of the MIs with respect to the various factors were estimated and plotted by using the Kaplan-Meier product-limit estimate. The MI survival distributions for each factor were compared with the log rank test for simple comparisons or the Cox regression for multiple variables.

Results: The overall success rates of MIs that remained stable during a mean treatment time of 19.2 ± 2.3 months was 93.43%; this was considerably higher than in previous reports. Only a few factors were found to be associated with statistically significant higher success rates of MIs, including deep bites, placement in the attached gingiva of the maxilla, and en-masse distalization of teeth.

Conclusions: The success rates of MIs in white patients were greater than the corresponding rates reported for Asian patients. Our results confirm the effectiveness of orthodontic MIs as temporary anchorage reinforcement devices and suggest various clinical factors as potential causes of failure. (Am J Orthod Dentofacial Orthop 2009;136:158.e1-158.e10)

A nchorage control is a fundamental prerequisite for efficient orthodontic treatment without complications. When properly chosen and applied, it minimizes the risks of side effects, increased treatment time, changes of original treatment plan during treatment, and possible extractions of additional teeth than initially planned. Successful osseointegration of implants, as reported by Brånemark et al, 1 encouraged many orthodontists to use dental implants for anchorage reinforcement. 2-6 However, some drawbacks are linked to their use for orthodontic purposes, such as the following 7: (1) specific surgical procedures required during placement and removal; (2) complicated clinical and laboratory procedures needed (fabrication of acrylic splints by taking imprints with additional implant copying systems to accurately transfer the implant position to cast models) to facilitate safe and precise implant placement; (3) delayed loading because of the waiting period necessary for osseointegration, increasing total treatment time; (4) possible placement locations limited to only edentulous or retromolar areas of the maxilla and mandible; (5) increased risk of damaging adjacent tissues (eg, nerves) or root injuries from improper placement, mainly because of their large dimensions; and (6) relatively high cost.

To overcome these problems, miniscrew implants (MIs) have been used as an alternative for orthodontic anchorage reinforcement. Their smaller dimensions facilitate placement in most sites of the jaws, even with root proximity (interdental areas) without an...
increased risk of root injury. Their placement and removal require no sophisticated or complicated surgical or laboratory procedures. Since osseointegration does not usually occur (except possibly to a small extent when they are used for a long time), they provide only temporary stationary anchorage. Consequently, there is no need for a waiting period for osseointegration, and they can be immediately loaded, decreasing total orthodontic treatment time.

During the past few years, clinical applications of MIs have been expanded to include various applications: correction of deep bite, closure of extraction spaces, correction of canted occlusal plane, alignment of dental midlines, extrusion of impacted canines, extrusion and uprighting of impacted molars, molar intrusion, distalization of either maxillary molars or mandibular teeth, en-masse retraction of anterior teeth, molar mesialization, maxillary third molar alignment, intermaxillary anchorage to correct sagittal discrepancies, and correction of vertical skeletal discrepancies that would otherwise require orthognathic surgery.

However, failure of MIs may occur, mainly if there is lack of stability at placement because of inadequate thickness of the cortical bone or irritation or inflammation of peri-implant tissues, especially in patients with poor oral hygiene. Researchers believe that MIs have already become efficient anchorage devices for orthodontic purposes and suggest them as the conventional anchorage devices of future everyday clinical practice. However, since failures of MIs can occur in more than 10% of patients, these claims still seem questionable.

In addition, most of aforementioned studies included patients of Asian origin, and only 2 used white patients. Asians have some different characteristics of craniofacial structures compared with white subjects. However, the success rates and the risk factors related to MIs between the 2 races seem to be similar. Accordingly, we hypothesized that there are no differences in the success rates and possible risk factors of MIs for orthodontic purposes and between the success rates of MIs in Asian and white patients. Our aims in this retrospective study were to investigate the success rates of MIs, used as TADs to support various types of orthodontic tooth movements, in relation to the risk factors associated with their use in white patients and compare our findings with the corresponding ones from other studies of Asian patients.

MATERIAL AND METHODS

Initially, the records of 141 white patients who received MIs as TADs during routine orthodontic treatment were retrospectively examined. Their corresponding records were consecutively chosen from the archives of the Department of Dentofacial Orthopedics and Orthodontics, Wroclaw Medical University, Wroclaw, Poland.

Since all patients received regular orthodontic treatment and MIs are commonly accepted in orthodontics, no ethical committee or review board approval for this study was obtained. Nevertheless, the detailed orthodontic treatment plan, including anchorage methodologies, surgical protocol, possible MI failures, and the probability of irritation or local inflammation, was explained, and informed consent was obtained from all patients before placement of the MIs.

Patients with the following available data were qualified for this study: (1) basic information including age, sex, and dental and skeletal relationships; (2) placement of MIs in at least 2 mouth quadrants; (3) dates of orthodontic treatment start, MI placement, completion of treatment, or failure and replacement of MIs; (4) type and length of MIs; (5) sites of MIs; (6) mode of loading; and (7) orthodontic movements achieved.

After applying these inclusion criteria, 11 patients were excluded. Consequently, 130 patients (77 female, 53 male; age range, 12-40 years) were included in this study.

In total, 350 self-tapping MIs from 2 manufacturers were evaluated: type A (n = 187), Absco Anchor MIs (Dentos, Daegu, South Korea), and type B (n = 163), Ortho Easy Pin MIs (Forestadent, Pforzheim, Germany).

These MIs had different diameters and lengths (Fig 1). Both were conical and narrowed from the head to the apex: type A from 1.3 to 1.2 mm, and type B from 1.6 to 1.2 mm. Two lengths were used: long MIs of 8 mm (total, 173: 97 Absco Anchor and 76 Ortho Easy Pin) and short MIs of 6 mm (total, 177: 90 Absco Anchor and 87 Ortho Easy Pin).

A database was established by using Excel software (version 2003, Microsoft, Redmond, Wash) to record details of all patients receiving MIs from October 2003, when the first MI was placed, to March 2008.

All MIs were placed by 1 operator (J.A.) under local anesthesia in healthy oral soft tissues. The following surgical procedure was used. After vertical incision (3-4 mm) and separating the wound margins, a pit was made with a 0.09-mm diameter burr. Subsequently, appropriate pilot drills were used under normal saline.
solution irrigation, as recommended by the clinicians who developed these MIs, to prepare the placement site. The screw head was adjusted at least 2 mm above the mucosa and exposed to the oral cavity through the incision. Ligature wire extensions, either passing through the hole of the MI head (type A) or surrounding it (type B), were used in every MI above the attached gingiva. No analgesics or antibiotics were prescribed after MI placement. Postoperative discomfort was minimal for all patients.

All type A MIs were placed with $30^\circ$ to $40^\circ$ angulation to the alveolar process in the maxilla and $10^\circ$ to $20^\circ$ angulation in the mandible; all type B MIs were placed with $90^\circ$ angulation in both jaws, according to the recommendations of the clinicians who developed them.

The patients were instructed to carefully clean the transmucosal portion of the MIs and maintain immaculate oral hygiene (proper toothbrush, brushing method, and mouthrinse) during treatment.

The MIs were loaded with orthodontic forces of 30 to 200 g with either elastics or nickel-titanium closed-coil springs (G&H Wire, Greenwood, Ind) after an initial healing period of 2 weeks, as usually suggested. Forces were applied both directly to the MIs (direct anchorage) and indirectly by fixation of anchoring teeth with the MIs via lacebacks or passive stiff wires (indirect anchorage) to achieve better torque and directional control, and to prevent gingiva impingement. These forces were used for the following orthodontic purposes: (1) en-masse retraction of the 6 anterior teeth in both arches, (2) en-masse distalization of the maxillary dental arch, (3) attachments for intermaxillary Class II elastics, (4) intrusion of the maxillary and mandibular incisors and molars, and (5) mesial movement of the mandibular second molars into adjacent extraction spaces.

Total treatment times, depending on the required dental displacements, varied from 8.2 to 26.1 months (mean, $19.2 \pm 2.3$ months). The MIs we examined remained in the oral cavity, serving as anchorage until the end of orthodontic treatment. MIs requiring replacement because of mobility were considered failures. If an MI failed, a new one was placed at least 10 weeks later at the same site or immediately at an adjacent site.

The mobility of the MIs was checked clinically with cotton tweezers 2 weeks (just before loading) and 6 months after placement.

The criteria of MI success were the following: (1) no inflammation of the soft tissues surrounding the MI, (2) no clinically detectable mobility, (3) anchorage resistance of the MI for 3 mm of tooth movement or more, and (4) anchorage function sustained until the end of orthodontic treatment.

Failure was defined as severe clinical mobility of an MI requiring replacement, spontaneous loss, or loss of an MI while checking its mobility with the cotton tweezers less than 8 months after placement or before the end of treatment.

Clinical variables possibly influencing the success rates of the MIs were categorized as patient-related, implant-related, location-related, and orthodontic-related, and assessed accordingly.

Patient-related factors included age ($\leq$20 years or $>20$ years); sex; and skeletal and dental relationships, grouping for Class (Class I, Class II, or Class III), mandibular angle (decreased, increased, or average), and overbite (increased, decreased, or normal).

Implant-related factors included implant type (Abso Anchor or Ortho Easy Pin) and length (short or long).

Location-related factors included placement side (right or left), vertical position (in the attached gingiva of the maxilla approximately 5 mm from the archwire level, in the oral mucosa of the maxilla up to 3 mm above the attached gingiva margin, in the attached gingiva of the mandible approximately 5 mm from the archwire level, or in the oral mucosa of the mandible up to 3 mm beneath the attached gingiva margin), and sagittal position (right side of the maxilla between the second premolar and the first molar, left side of the maxilla between the second premolar and the first molar, midline of the maxilla between the central incisors, right side of the mandible between the first and second molars, left side of the mandible between the first and second molars, right side of the mandible between the first and second premolars, left side of the mandible between the first and second premolars, or midline of the mandible between the central incisors).

Fig 1. Miniscrew implants evaluated in this study: A, Abso Anchor (short length, 6 mm); B, Abso Anchor (long length, 8 mm); C, Ortho Easy Pin (short length, 6 mm); D, Ortho Easy Pin (long length, 8 mm).
Orthodontic-related factors included mode of loading (direct or indirect); and orthodontic tooth movements with MI anchorage, including en-masse tooth retraction (application of a horizontal force resulting in a minimum of 4 mm of space closure per side), en-masse distalization (up to 4 mm of distal movement of the maxillary teeth in both quadrants), Class II traction (application of internmaxillary Class II elastics, 3/16 in, 150 g of force per side), intrusion of molars or incisors (application of a vertical force displacing teeth 2-3 mm), and uprighting and mesial movement of the mandibular second molars into adjacent extraction spaces (application of a horizontal force displacing teeth 7-10 mm).

Statistical analysis

Descriptive statistics were initially performed to calculate the overall success rate of the MIs, as well as their specific success rates with regard to the patients’ age, sex, and dental and skeletal relationships, and for type and length of the MIs, side of placement, inferior-superior or anteroposterior position, mode of loading, and orthodontic tooth movements.

Furthermore, the survival curves of the MIs with respect to patient-, implant-, location-, and orthodontic-related factors were estimated and plotted by using the Kaplan-Meier product-limit estimate. Since the data were continuous, the MI survival distributions for each factor under investigation were then compared with the log rank test for simple comparisons, such as sex, or the Cox regression for the analysis of multiple variables, such as dental movements.

The data were statistically analyzed with SPSS software (version 15.0, SPSS, Chicago, Ill). The statistical significance was set at P <0.05 for all tests.

RESULTS

Ten of the 350 MIs had partial mobility during orthodontic treatment and were retightened, whereas 23 MIs failed during treatment and were replaced.

The overall and detailed success rates of the MIs; the patient-, implant-, location-, and orthodontic-related factors; and the corresponding comparisons are shown in Table I. The results of the survival analysis of the MIs for the various factors investigated are shown with Kaplan-Meier curves in Figures 2 through 9.

The overall success rate of the MIs in this study was 93.43% (327 of 350 MIs).

Of the patient-related factors, only the vertical dimension seemed to be important in the success rates; patients with deep bite had a significantly higher success rate (97.29%) than patients with open bite (88.88%) or normal overbite (95.33%) (P = 0.023) (Table I, Fig 2). No other patient-related factor showed a significant difference among the various subgroups. Nonetheless, greater success rates were found in patients aged >20 years (93.93%) (Fig 3), female patients (93.92%) (Fig 4), patients with Class III malocclusion (100%) (Fig 5), and patients with an average mandibular angle (96.15%) (Fig 6).

Of the implant-related factors, neither type nor length of the MIs significantly affected their success rates, although a tendency for higher success rates was observed for type A (Abso Anchor) (94.11%) and long (94.79%) MIs (Fig 7, Table I).

Evaluation of the location-related factors showed that the success rates of MIs are not associated with the jaw (maxilla or mandible) or side of placement (right, midline, or left) (Fig 8). However, for the vertical position of placement, we found that MIs in the attached gingiva of the maxilla had significantly higher success rates (98.03%) than in all other locations (P = 0.021) (Table I). Furthermore, for the sagittal position of placement, we found that MIs in the right side of the mandible between the first and second molars had the lowest success rates (87.71%) compared with all other locations (P = 0.050, Table I).

Of the orthodontic-related factors, the success rates of MIs were not significantly associated with mode of loading, although indirect loading seemed to have a higher rate (96.96%) than direct loading (92.60%) (Fig 9, Table I). Of the dental movements with MIs, en-masse distalization of teeth had the highest success rate (98.11%) (P = 0.016), and intrusion of molars had the lowest rate (88.57%) (P = 0.046, Table I).

DISCUSSION

The stability of MIs after loading with orthodontic forces is still controversial. First, many studies of MIs used as TADs for orthodontic purposes were either preliminary studies based on few patients or case reports. Second, few studies reported the overall success or failure rates of MIs, as well as possible correlations of these rates with various potential risk factors. In addition, in most of these studies, the patient samples were Asian; only 2 investigations evaluated the success rates in white patients.

Although MIs seem to be efficient tools for providing temporary stationary anchorage, especially in less compliant or noncompliant patients, certain risks jeopardizing their stability can arise either before or after orthodontic loading, despite the clinician’s strict adherence to the placement protocols.

Risk factors thought to be responsible for MI failures include inflammation of soft tissues surrounding the MIs...
mainly from bad oral hygiene, the surgical techniques used for placement, the MI’s inability to resist reciprocal forces used for orthodontic tooth movement, the type and length of the MI, placement position, mode of loading (direct or indirect), mode of force application (torquing forces), or certain tooth movements. To strengthen, as much as possible, the results of this retrospective investigation, we tried to include many MIs (n = 350) that were used for orthodontic purposes in a relative large number of consecutively chosen patients (n = 130) by 1 operator using a standardized surgical technique. Nevertheless, the lack of a control group could be regarded as a shortcoming that might weaken the validity of this study. However, a control sample of untreated patients would be unethical, since they would not have benefited from the MIs. In addition, many risk factors possibly associated with the success rates of MIs might also weaken these results. Data from such a study are difficult to interpret, and the possibility of finding statistical significance from chance alone is relatively high.

The overall success rate of the MIs in this study in white patients was 93.43%; this is high when compared with the rates in studies of Asian patients (75.20%-91.60%) (Table II). Only 2 studies evaluated the success rates of MIs used for orthodontic anchorage reinforcement in white patients, with only a few factors.
associated with their stability, and found success rates between 86.80% and 90.71%; this was similar to the rates for Asian patients. The same tendency was almost always observed when comparing the detailed success rates with regard to the various factors that can influence the stability of MIs in this study with the corresponding results of the above-mentioned studies (Table II). The higher success rates of MIs we observed might be at least partially because they were placed by the same operator, who strictly complied with the protocols suggested by the developers of the 2 implant systems. Race might be a factor influencing these results. However, since there are several other risk factors involved with MIs, this statement requires further investigation.

No previous study evaluated the success rates of MIs in relation to the patients’ dental vertical relationships. Open bite was a negative factor significantly influencing the stability of the MIs in our study. However, this was not evident considering the patients’ skeletal vertical relationships, in contrast to the findings of Miyawaki.
et al\textsuperscript{32} and Baek et al,\textsuperscript{24} who observed lower success rates in patients with increased mandibular angles (Table II). The lower success rates of MIs in patients with open bites or increased mandibular angles might be because these patients usually have thin cortical bones, the volume of which significantly contributes to the mechanical retention of nonosseointegrated MIs. Although the success rates of MIs were not significantly associated with implant type and length, they were higher than those in other investigations.\textsuperscript{25,29}

This study showed no difference in success rates of MIs for maxillary or mandibular placement in contrast to the results of Chen et al\textsuperscript{27} and Park et al,\textsuperscript{30} who found lower success rates for the MIs in the mandibles of Asian patients. Cortical bone thickness of the mandible that might cause bone overheating while drilling and the short zone of attached gingiva have been suggested as causes of these significantly lower success rates of MIs in the mandible. In contrast to Luzi et al,\textsuperscript{28} similar results to ours were achieved also by Wiechmann et al\textsuperscript{29} that were not necessarily correlated with anatomic factors, such as cortical bone thickness or level of the attached gingiva. The low success rates observed by these clinicians in the mandible were rather due to either improper selection of MI diameter (1.0 mm) or placement site (lingual).

Placement of MIs in the left quadrant of the dental arch, although not significant in our evaluation, seemed to have a higher success rate than on the right side as also reported previously.\textsuperscript{30} A possible explanation for this might be better oral hygiene on the left side of the oral cavity that is usually observed in right-handed patients, who are the majority.\textsuperscript{45}

With regard to the vertical position of MIs, their placement in the attached gingiva of the maxilla was associated with significantly higher success rates, in contrast to the results of Park et al,\textsuperscript{30} who found higher success rates when MIs were placed in the oral mucosa of maxilla. Furthermore, concerning sagittal placement, it was found that MIs on the right side of the mandible between the first and second molars had significantly lower success rates; this agrees with the results of Kuroda et al.\textsuperscript{25} In contrast, Chen et al\textsuperscript{27} found the lowest success rates on either side of the mandible between the first and second premolars.

No association between the success rates of MIs and mode of loading (direct or indirect) was found in this study. Nonetheless, the results concerning MI stability in relation to the direction of forces applied might lead to the conclusion that vertical forces applied to MIs seem to be responsible for more failures than horizontal forces. In our evaluation, MIs serving as TADs for en-masse distalization of maxillary teeth had the highest success rates, whereas MIs used for molar intrusion had the lowest rates. The latter finding agrees with the results of Kuroda et al.\textsuperscript{25}
CONCLUSIONS

Our results showed higher success rates of MIs used as TADs for orthodontic purposes in white patients than the corresponding rates reported for Asian patients. Several factors might influence the stability of MIs, including patients’ dental vertical relationships, vertical or sagittal placement of MIs, and the specific dental movements supported with their use.

Our results confirm the effectiveness of orthodontic MIs as temporary anchorage reinforcement devices and suggest various clinical factors as potential causes of failures.

We thank the following manufacturers that donated the MIs and some materials for this study: Orto Trading, Warsaw, Poland; Forestadent, Pforzheim, Germany; and G&H Wire, Greenwood, Ind.

### Table II. Comparison of the success rates of MIs in this and previous studies

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<td>Present study</td>
<td>Luzi et al(^{28})</td>
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<td>Overall success rate (%)</td>
<td>93.43 (327/350)</td>
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<td>Patient-related factors</td>
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\(^{28}\) Luzi et al, \(^{29}\) Wiechmann et al, \(^{32}\) Miyawaki et al, \(^{27}\) Chen et al, \(^{30}\) Park et al, \(^{25}\) Kuroda et al, \(^{24}\) Baek et al, \(^{21}\) Moon et al.
REFERENCES