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ORIGINAL ARTICLE

Revisiting the stability of mini-implants used for orthodontic anchorage

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Background/Purpose: The aim of this study is to comprehensively analyze the potential factors affecting the failure rates of three types of mini-implants used for orthodontic anchorage.
Methods: Data were collected on 727 mini-implants (miniplates, predrilled titanium miniscrews, and self-drilling stainless steel miniscrews) in 220 patients. The factors related to mini-implant failure were investigated using a Chi-square test for univariate analysis and a generalized estimating equation model for multivariate analysis.
Results: The failure rate for miniplates was significantly lower than for miniscrews. All types of mini-implants, especially the self-drilling stainless steel miniscrews, showed decreased stability if the previous implantation had failed. The stability of predrilled titanium miniscrews and self-drilling stainless steel miniscrews were comparable at the first implantation. However, the failure rate of stainless steel miniscrews increased at the second implantation. The univariate analysis showed that the following variables had a significant influence on the failure rates of mini-implants: age of patient, type of mini-implant, site of implantation, and characteristics of the soft tissue around the mini-implants. The generalized estimating equation analysis revealed that mini-implants with miniscrews used in patients younger than 35 years, subjected to orthodontic loading after 30 days and implanted on the alveolar bone ridge, have a significantly higher risk of failure.
Conclusion: This study revealed that once the dental surgeon becomes familiar with the procedure, the stability of orthodontic mini-implants depends on the type of mini-implant, age of the patient, implantation site, and the healing time of the mini-implant. Miniplates are a more feasible anchorage system when miniscrews fail repeatedly.

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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Introduction

Anchorage is critical in achieving successful orthodontic treatment. The clinical feasibility of mini-implants for use as orthodontic anchors has been documented by numerous papers published in the past decade.[1] Compared with endosseous dental implants, orthodontic mini-implants are smaller in size, less expensive, and more easily placed and removed.[2–5] Orthodontic mini-implants include miniplates[6,7] and miniscrews.[8–10] Mini-implants can be stabilized using mechanical interlocking between miniscrews and the surrounding bone tissue. It is possible to start orthodontic loading immediately after miniscrew implantation if the loading is limited to a light force.[11,12] The loosening of mini-implants may occur shortly after implantation, however, and get progressively worse after loading.

A systematic review by Schatzle et al[1] indicated that the failure rate of orthodontic mini-implants was 7.3% for miniplates and 16.4% for miniscrews. Moreover, miniscrews with a diameter >2 mm exhibited an approximately twofold lower risk of failure than miniscrews with a diameter <1.2 mm. In addition to the mini-implant type, various factors have been identified that are associated with mini-implant failure rate, such as the patient's age, mandibular plane angle,[13] bone density,[14] reason for using a mini-implant, duration of healing,[15] inflammation,[13,16] root proximity,[17] and the characteristics of the surrounding soft tissue.[18] Common statistical methods, such as analysis of variance or regression models, require the assumption of independent observations. Many previous studies have reported factors affecting mini-implant stability by assuming the independence of mini-implants placed at different locations in the same patient. A correlation may exist among different mini-implants, however, if the host effect is taken into account. Generalized estimating equation (GEE) analysis is therefore a more appropriate method for analyzing correlated data that arise from situations such as longitudinal studies or clustering.[19,20]

Most orthodontic miniscrews are made from titanium or its alloys; however, some manufacturers have proposed stainless steel miniscrews be used as orthodontic anchors. Decreased bone interface has been found around stainless steel screws compared to titanium screws.[21] Stainless steel miniscrews exhibit distinct mechanical properties, such as high flexural strength and torsional resistance,[22,23] thus minimizing the risk of fracturing during insertion. In addition, due to the sharp tip of the stainless steel miniscrews, they can be inserted into the alveolar bone and infrazygomatic crest without the need for a predrilling procedure.[15] The aim of this study was to revisit the failure rates and the factors affecting the stability of orthodontic mini-implants, including titanium miniplates, predrilled titanium miniscrews, and self-drilling stainless steel miniscrews. We chose to use the statistically more powerful GEE model to analyze the clustering data arising from multiple mini-implants used in single patients.

Patients and methods

The records relating to 727 orthodontic mini-implants were retrospectively collected from 220 patients (66 males and 154 females, with a mean age of 29.3 years old) enrolled at the Orthodontic Department, National Taiwan University Hospital during the period September 2007 to September 2012. The number of mini-implants used for a single patient ranged from one to eight (34 patients had one, 82 patients had two, 26 patients had three, 49 patients had four, 10 patients had five, 13 patients had six, five patients had seven and one patient had eight mini-implants). The majority of the patients (87%, 191/220) had four or fewer mini-implants installed. There were three types of mini-implants (Fig. 1): 159 titanium miniplates (P), 388 predrilled titanium miniscrews (L-miniscrew; Leibinger, Muhlheim-Stelten, Germany), and 180 self-drilling stainless steel miniscrews (J-miniscrew; Kwung-Jer, Taipei, Taiwan). All of the mini-implants were installed by an experienced oral surgeon following procedures described previously.[14]

A mini-implant was considered to have failed if there was significant loosening or mobility that could not withstand orthodontic loading. For patients with mini-implant failure, a new mini-implant was installed if skeletal anchorage was still required for further treatment. The present study included 727 mini-implants, 643 of which were initially implanted and the other 84 were used for reimplantation. The failure rates of various mini-implants were calculated according to the type of mini-implant and the time of implantation (Table 1). The data subjected to univariate and multivariate statistical analysis were limited to the 643 mini-implants inserted initially implanted.

Patients whose notes contained the following data were included in this study: sex, age, type of malocclusion (Class I, II, or III), and facial divergence (Sella-Nasion to Mandibular Plane, mandibular plane angle, high: SN-MP $> 45°$; average: $45° \geq$ SN-MP $\geq 25°$; or low: SN-MP $< 25°$). The implantation-related data included the following: the type of mini-implant − P: miniplate, L: predrilled titanium miniscrew, and J: self-drilling stainless steel miniscrew; where the mini-implant was inserted, such as arch (upper or lower), site (buccal, palatal, or edentulous alveolar ridge), or location (anterior or posterior to second premolars); the bone density at the implantation site (D2, D2−D3, D3, D4); the type of soft tissue around the mini-implant (attached gingiva, mucogingival junction, or movable mucosa); soft tissue inflammation (none, mild, moderate, or severe) around the mini-implant 1−2 weeks after insertion; and the duration of healing ($\leq$ or $>$30 days after insertion). Moreover, the bone density of the implantation site was recorded during mini-implant installation, based on the operator's hands-on perception of the drilling resistance, according to Misch.[24] The degree of soft tissue inflammation around the mini-implants was evaluated during the 2nd week after insertion by the operator according to criteria modified from the gingival index.[25] In addition, the association between mini-implant failure and dentofacial characteristics was investigated by analyzing commonly-used cephalometric measurements, including SNA, SNB, ANB, A-Nv, Pog-Nv, SN-FH, SN-OP, SN-MP, U1-SN, U1-L1, L1-OP, L1-MP.[15]

Univariate analysis was conducted by using the Chi-square test to check the variables potentially associated with mini-implant stability. The number of mini-implants used in individual patients ranged from one to six, indicating a maximal cluster size of six. The cluster-correlated data were further analyzed with a GEE model using the R