Original Article

Evaluation of the Success and Complication Rates of Self-Drilling Orthodontic Mini-Implants

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Abstract

Aims: Orthodontic mini-implants are important devices for successful anchorage management in orthodontics; however, the survival of these devices depends on several clinical factors. The aim of our study was to calculate the success and complication rates of orthodontic mini-implants. **Materials and Methods:** In this retrospective study, patients of our orthodontic department were enrolled, getting overall 59 orthodontic mini-implants during their orthodontic treatment in a 2-year period. Every patient had one or more of the 1.6 mm × 8 mm in size self-drilling mini-implants (Jeil Dual Top Anchor System, Jeil Medical Corp., Seoul, Korea). Screw loading was performed immediately after insertions, keeping tension forces under 150 g. Soft tissue and bone infections, implant mobility and screw loss, implant fracture, and neighboring tooth injury were registered. Relationships between variables were tested using the Chi-square test for statistical significance. **Results:** The success rate of the orthodontic mini-implants was 89.8% in this study while the average loading period was 8.1 months. Soft-tissue infections varied between 6.3% and 33.3% of the cases while screw mobility varied between 3.1% and 20.8% of the cases regarding the anatomic localization. Screw mobility was significantly more frequent in the buccal fold than in the palate ($P = 0.034$). Screw mobility was significantly more frequent in the buccal fold than in the palate ($P = 0.034$) and screw mobility was found more frequently in case of intrusions than by extrusions ($P = 0.036$). **Conclusions:** The overall success rate of mini-implants was found acceptable in this study, however, screw mobility in the buccal fold showed a high incidence, suggesting the thorough consideration of the immediate loading by buccal mini-implants.

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Introduction

The keystone of a successful orthodontic treatment is assuring the proper anchorage. According to the definition by Proffit *et al.*,[1] "anchorage is the prevention of unwanted dental dislocation." Anchorage methods in a traditional orthodontic treatment can be external (headgear) and intraoral (transpalatal arch, lingual arch intermaxillary latex pulling) appliances. Due to the disadvantages (patient cooperation, loss of anchorage, esthetic disadvantages, and overexertion of teeth) of external appliances, among the temporary anchorage devices, mini-screws have become more popular in recent times. The screws of a diameter of 1.4–2.5 mm and 6–12 mm length allow immediate loading thus shortening treatment time. Both their insertion and removal due to lack of osseointegration are simple. In self-tapping mini-screws, a predrilling is needed before insertion whereas in self-drilling mini-screws, there is no need for this.[2] Due to their numerous advantages, they can be applied on a wide field of indications. Besides *en masse* retraction[3] and intrusion of molar teeth, they are

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useful in the treatment of anterior open bite[4] and deep bite.[5] Alignment of impacted canine teeth assisted with a skeletal anchorage is associated with a decreased risk of complications and a shortened treatment time.[6]

The overall success rate of mini-implants was ranged from 79% to 98.2%, considering 5332 screws.[7] Papageorgiou *et al*.[8] defined the success rate of mini-screws as 86.5% based on their study involving 2281 patients. Besides the advantages and easy application, however, the usage of mini-screws is associated with failures as well. Injuries to the root of the adjacent teeth, loosening, or fracture of the screw and inflammation around the screw can occur.

The objective of our retrospective study was to detect the success rate of mini-screws in a clinical orthodontic practice, in relation to age, gender, localization, and type of orthodontic procedure.

Materials and Methods

This retrospective study involved patients treated by fixed orthodontic appliances in combination with orthodontic mini-screws between November 2014 and November 2016 in our departments (Department of Paediatric and Adolescent Dentistry and Department of Oral and Maxillofacial Surgery, University of Pécs, Pécs, Hungary). This retrospective study was approved by the Institutional Regional Ethics Committee (PTE/64934/2016). In every of the involved patients, one or more self-drilling mini-screws (Jeil Dual Top Anchor System, Jeil Medical Corp., Seoul, Korea) with a dimension of 1.6 mm × 8 mm were inserted. Smoking patients and patients with any general systemic diseases were excluded from this study. Orthodontic mini-implants were considered successful when they proved a perfect skeletal anchorage during the entire treatment period (independent from the period's length) without sign of mobility. In contrast, screws showing mobility or loosening (with or without subjective complaints), peri-implant infection, or neighboring tooth injury occurred, were considered as failures. One month after, screw placements or in case of appearing subjective complaints (neighboring tooth sensitivity, spontaneous pain, pain on chewing, or triggered by cold foods or drinks) immediately pulpal vitality test and percussion test were performed. In addition, periapical radiographs were taken to control the desired tooth movement and identify possible periodontal processes. In case of periradicular radiolucencies (either at the apex or on the lateral root surfaces in the near of the screw), or in case of suspected root resorption signs or when radiolucencies were present around the mini-implant screws, further local, small field of view cone-beam computed tomography (CBCT) was indicated.

Before screw insertions, the correct location of the implants was determined by physical and radiological investigations. Radiological investigations included panoramic and periapical radiographs, and in some cases, CBCT.

After the application of an antiseptic mouthwash (chlorhexidine 0.2%), screw insertions were performed in terminal local infiltration anesthesia (articaine with epinephrine) by an experienced oral surgeon. Every screw was placed hand driven with the screwdriver tool of the mini-implant system. The placed screws were loaded immediately. To choose the adequate spring, it's traction force was measured with the help of a force gauge (Haldex LMV 1097, Halda Co., Tullinge, Sweden). Traction forces were kept under 150 g according to relevant literature.[7,9]

When the mini-screw served as an anchorage to the movement of an angulated impacted tooth (e.g., canine) or to an up-righting maneuver, the implantation was performed simultaneously with the exploration surgery of the unerupted (angulated) permanent tooth.

The data collection and statistical analyses were performed with SPSS® version 22.0 (SPSS, Chicago, IL, USA). To estimate the adequate sample size, authors used the following formula:

$$\frac{Z_{1-\frac{\alpha^2}{2}}\, p(1-p)}{d^2} \text{s}$$

Where Z was 1.96 (at 5% type I error it is standard), *P* was 0.04 (the expected failure rate of 4%, according to previous studies) and d was 0.05 (as the absolute error, precision).[10] When calculating with 4% of suspected failure rate, the required sample size should be 59 cases [$(1.96^2 \times 0.04\ (1-0.04))/0.05^2 = 59$].

To compare the occurrence of screw mobility and infection between different localizations or different tooth movements, the Pearson's Chi-square test was used. The significance level was set to 5%.

Results

In the given period, 47 patients were involved in our study, receiving 59 mini-screws altogether. The average loading time of the screws was 8.1 (±3.3) months. Successful application of the screws was feasible in 89.8% of all orthodontic treatments.

Distribution of screws according to gender, jaws, localization, and treatments performed is demonstrated in Table 1.

The success of mini-screws was not significantly influenced by age and gender of patients. The prevalence

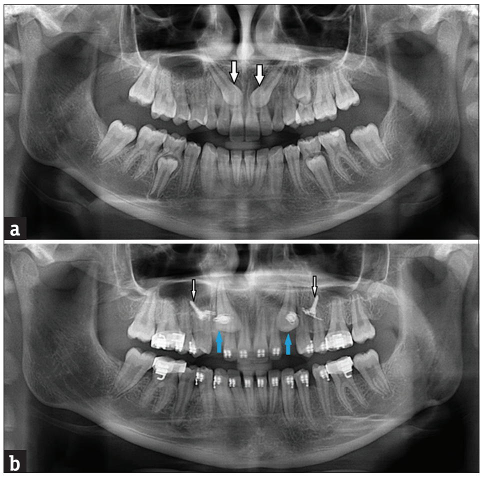

Figure 1: (a) In the initial orthopantomograph, the two mesially inclined impacted canines can be observed (arrows). (b) With the help of the inserted orthodontic mini-implants (white arrows), the angulation of the canines was modified with a traction of the canines' crowns to a distal direction (blue arrows). Mini-screws in the palate served as an anchorage for the traction

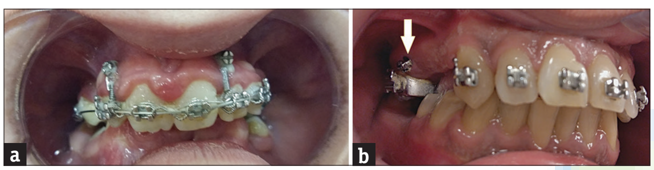

Figure 3: (a) Gingivitis and plaque accumulation are seen at the permanent teeth and around the screws. Implants served as an anchorage of incisors' intrusion. (b) The surrounding mucosa of the buccally positioned mini-screw (arrow) shows gingivitis while at the ring on the first molar an intense plaque accumulation is seen. Mini-implant served as an anchorage stabilization

of failed mini-screws is shown in Table 2, in relation to the anatomical region and the orthodontic treatment. Peri-implant inflammation was found in 6 cases out of 59 (10.2%). In respect to localization, the prevalence of inflammation in the field of the palate (6.25%) and buccal fold (8.3%) was comparable. The salient result of 33.3% in the ascending ramus results from the small number of cases in that region (one of three cases).

On the other hand, considering localizations, a significant difference could be observed in relation to loosening of the screw. Loosening of the screw in palatal insertion presented in 3.1%, whereas it was observed in 20.8% of the buccal cases ($P = 0.034$). However, loosening of the screw presented only in 6 cases (6/59 = 10.2%).

Considering the type of the orthodontic treatment, screw loosening was significantly more frequent in case of intrusions (2/8), than by extrusions (1/32) ($P = 0.036$).

During the research period, neighboring tooth root injury was not detected on radiographs or CBCT images, and screw removal was not indicated. In case of screw mobility, radiographic examinations showed increased radiolucency around the screws in 6 from the 6 cases

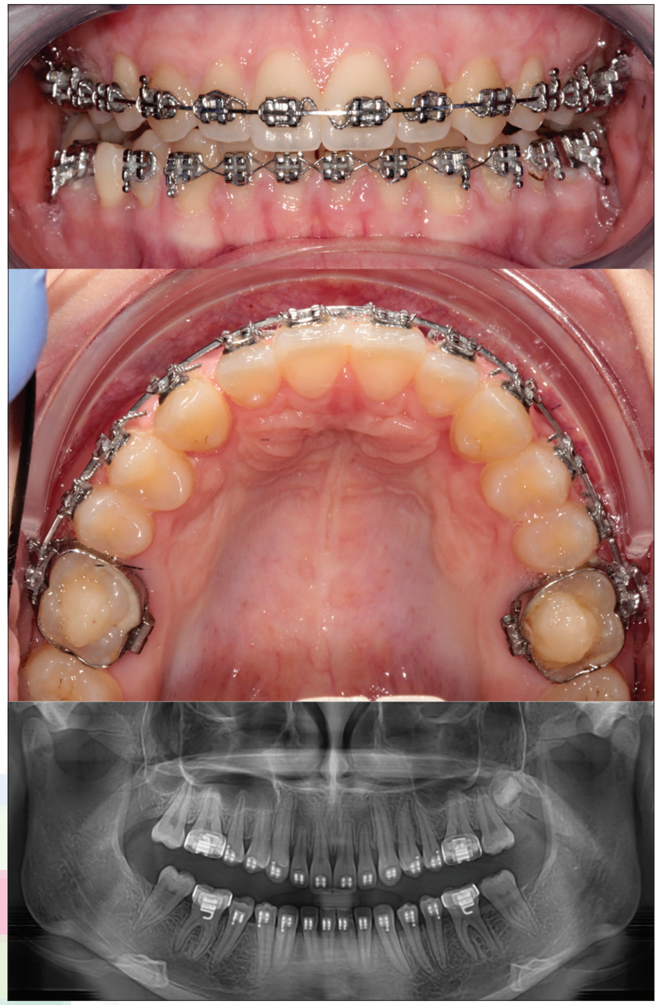

Figure 2: With the help of the mini-screws, the normal occlusion including the normal position of the canines was constructed after 26 months of orthodontic treatment

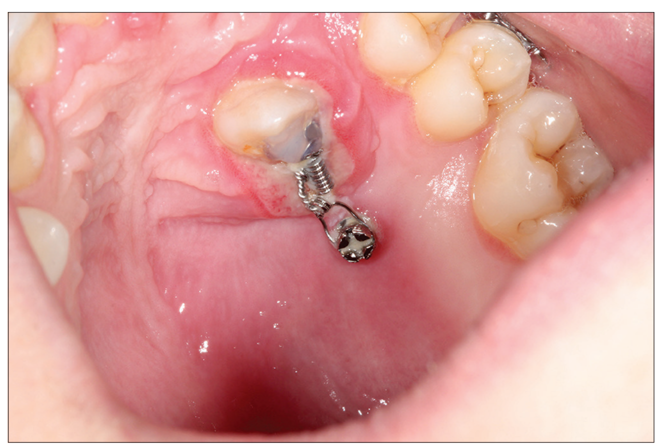

Figure 4: Gingivitis and pus formation are seen around the palatinally positioned mini-screw. The infection was treated by local disinfectants (iodine-containing solution and chlorhexidine gel) while the screw was stabile in the loading period

while at stabile screws, it was not observed. A successful case is interpreted in Figures 1 and 2 while cases with different complications are shown in Figures 3 and 4.

Table 1: Distribution of screw placements

Variable	Frequency (%)
Sex	
Male	15 (25.4)
Female	44 (74.6)
Age (years)	
<20	40 (67.8)
20-30	15 (25.4)
>30	4 (6.8)
Screw location (jaw)	
Maxilla	54 (91.5)
Mandible	5 (8.5)
Screw location (side)	
Right	33 (55.9)
Left	26 (44.1)
Screw location (region of the jaw)	
Front	10 (16.9)
Lateral	49 (83.1)
Screw location (anatomic localization)	
Palate	32 (54.2)
Buccal fold	24 (40.7)
Ascending ramus	3 (5.1)
Type of orthodontic treatment	
Extrusion of impacted tooth	32 (54.2)
Intrusion	8 (13.6)
Distalization	16 (27.1)
Uprighting of submerged tooth	3 (5.1)

Table 2: Incidence of complications

Type of complication	Localization/treatment	Number of failed/total cases regarding localization or treatment (%)	*P**
Inflammation	Palate	2/32 (6.3)	NS
	Buccal fold	3/24 (12.5)	
	Ascending ramus	1/3 (33.3)	
Screw mobility	Palate	1/32 (3.1)[A]	0.034
	Buccal fold	5/24 (20.8)[B]	
	Ascending ramus	0/3 (0)	
	Extrusion of impacted tooth	1/32 (3.1)[A]	0.036
	Intrusion	2/8 (25.0)[B]	
	Distalization	3/16 (18.8)	
	Uprighting of submerged tooth	0/3 (0)	
Screw fracture	Ascending ramus	1/3 (33.3)	-

[A,B]Significant differences. *Chi-square test, $P \leq 0.05$, NS=Not significant

Discussion

Based on survival and success rates, orthodontic mini-implants can assist the development of a stable anchorage excellently in orthodontic treatments. However, several critical issues must be considered to prevent complications. One of these issues is the location of insertion. According to the literature, screws becoming loose showed a higher proportion if not inserted into keratinized mucosa (e.g., out of 16 implants 4 losses).[11] In their study, Park[12] was investigating the basic factors in the successful application of mini-screws. Their results were to ours to some extent, inasmuch as inflammation was more frequently detected in mini-screws inserted into the buccal surface of the alveolar process. This is due to the diversity of the mucosa reflected in labial areas being more exposed to the impact of muscle forces and the variable proportion of attached gingiva. The tense mucosa of the palate is a more beneficial area for mini-screws.[12] This is supported by our own research results, according to which loosening of the screw during an orthodontic treatment presented in 3.1% if mini-implants inserted in the palate, whereas in cases where buccal insertion served as a location for skeletal anchorage, screw loosening was observed in 20.8%. To achieve the intrusion of molar teeth, Lee *et al.*[13] inserted mini-screws in the palatal suture. Keratinized soft tissue with a very thin bone layer allowed a faster intrusion and patients reported about a better state of general well-being.[13]

Stability is influenced by the quality and quantity of cortical bone. If mini-screws are inserted into a cortical bone thinner than 1 mm, skeletal anchorage is not ensured.[14] Computer tomography is the most precise diagnostic tool to determine the thickness of cortical bone and the best anatomical location for an insertion.[15] Preferred areas for a skeletal anchorage include the interdental areas of maxilla's alveolar process and the palate while in case of the mandible, these involve the retromolar area and the inter-radicular, interdental areas of the alveolar process.[16] Our study results indicated, that screw loss is more frequent in the area of buccal fold, which is often not as ideal, regarding the thickness of the cortical, than the area of the palate.[17] However, it did not play a role in the incidence of inflammation, which presented in the same ratio when the two regions were compared in the current study.

Motoyoshi *et al.*[18] examined the success rate of mini-screws in 57 patients (aged 11.7–36.1) undergoing orthodontic treatment. The aim of skeletal anchorage was to retract the front teeth following the extraction of the upper premolar teeth, loaded with 2 N orthodontic forces. Poorest results (63.8%) were found in teenagers who received the force load within <1 month. In similar interventions, if the load to the mini-screw started only 3 months later, treatment was more successful (97.2%).[18] According to our results, mini-screws inserted for a similar treatment and exposed to the load immediately proved successful only in 81.2%

and due to loosening of the screw the anchorage tools were removed in almost one-fifth of cases when a distalization happened. According to our results, screw mobility was more frequent in intrusion cases, than in extrusions, however, it is important to note, that during intrusions, screws were placed buccally while in extrusion cases, the vast majority of the screws were placed palatinally.

Literature data are divided regarding the necessary healing time before the load of the implant and the optimal time is also debated. Using small titanium screws for orthodontic anchorage, research results in dogs showed that the biggest success rate (97%–100%) was achieved with load after a 3-week healing time.[19] If titanium implants were used as anchorage within a week, torsion fracture could occur.[20] Büchter *et al*.[21] found in their research on pigs that in case of immediate load under 900 cN, no screw loss was present. Based on these results, we can conclude that the immediate load on mini-screws is possible without complications while the proper choice of power may play a major role in reaching stability.

Preliminary drilling is a key issue in case of mini-screws. Primary stability of mini-screws inserted on preliminary drilling is significantly larger than that of the ones inserted without a predrilling. With the course of time, however, stability of mini-screws requiring preliminary drilling may decrease significantly primarily due to the reduced trabecular bone mass.[2] Moreover, the method of insertion can determine the temperature forming in the bone. Based on our *in vitro* research results, temperature in the bone was raised by 7.6°C at a 1200 rpm/min (diameter of the preliminary drill was 1 mm) on predrilling. If preliminary drilling was performed using a worn drill, the increased temperature was found to be 12.3°C.[22] If these high-temperature values persist for more than a minute, it jeopardizes the survival of the implant surrounding bone, leading to thermal osteonecrosis.[23] When mini-screws were inserted hand-driven, there was no significant difference between insertion with or without predrilling (with predrilling: 11.8°C ± 2.1°C; without predrilling: 11.3°C ± 2.4°C).[22] In contrast, when mini-screws were cooled down to less than 0°C before insertions, maximum intraosseous temperatures were reduced to ~6.6°C average maximum values during hand-driven insertions.[24]

Since stability of mini-screws is provided by a mechanical retention, in contrast to enosseal dental implants, diameter and length of the mini-screw are thought not to play a role in the final results.[23] At the same time, Tseng *et al*.[25] reported about a 100% success when 12 mm long screws were applied. In contrast, according to others, a longer mini-screw can increase stability; however, their usage is associated with a higher risk for root damage.[26] Therefore, screws of a 6–8 mm length are recommended for a safe usage,[26] and this recommendation was followed even in our study.

Pan *et al*.[27] investigated the primary stability of mini-screws made of diverse materials having a diameter of 2 mm. The resonance frequency of the screws was determined when inserted into the bone (cortical 2 mm of thickness). The screws were of 10 and 12 mm length and made of titanium alloy. Measurements were registered at 2.2 and 6 mm of insertion depth.[27] Measurements failed to demonstrate a significant difference between mini-implants made of different materials. In contrast to this finding, however, insertion depth has a major role in providing stability. Deeper insertion is important not only for achieving better end results but also to lessen the stress between the bone and the surface of the mini-implant. This stress results from tipping movements on screw insertion.[21] Screw System Dual Top (Jeil, Korea) applied in our study as well, provided a significantly better primary stability compared to another system of similar dimension (of a 1.6 mm diameter and a 8–10 mm length), called Tomas Pin (Dentaurum, Germany) based on the measurements of Wilmes and Drescher[28] According to these authors in case of dual top screws better results are due to the cylindrical form of the intraosseal part. Fracture in the screw, stress developing in the bone can be avoided by choosing the preliminary drill of optimal diameter. On evaluating the insertion torque, they concluded that for clinical applications it is recommended to use a preliminary drill of a diameter 0.5 mm smaller than that of the implant.[28]

The incidence of screw fracture is 0.5%–1.4%.[29] Most frequently fracture occurs in the cervical part of the screw since mechanical stress is concentrating in this point. This complication can be avoided, reduced to a great extent by choosing the right insertion torque (3–10 Ncm).[30] In case of the 59 inserted screws in our study, only one fracture was observed, in the ramus region.

Injuries to the root of adjacent teeth can also lead to complications when inserting mini-screws. One study determined its incidence as 1.3%[31] while another study found a higher prevalence (3%).[32]

To check root injuries, a control radiograph and an examination of the vitality of adjacent teeth are needed, especially if the patient complaints of pain. Injury to the soft tissues is a very rare complication. The risk for an inflammation around the mini-screw can be reduced to the minimum with appropriate oral hygiene measures. In a 5-year follow-up study by Leonhardt *et al*.,[33] it was recommended, to apply a systemic antibiotic treatment complemented with a hydrogen-peroxide wash to treat peri-implantitis as a successful therapy in 58%.

Conclusions

Inflammatory complications frequently develop even with careful insertion as a result of the patient's poor oral hygiene. Our study findings showed that application of mini-screws of 1.6 mm × 8 mm inserted in the buccal fold is often associated with loosening of the implant upon immediate load. In contrast, mini-screws of palatal localization usually provide excellent skeletal anchorage. Optimal healing time and determining the right force of load to be applied can be subjects of future studies, the result of which can help further increase the success rate of mini-screws.

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Conflicts of interest

There are no conflicts of interest.

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