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The success rate of 2619 consecutively inserted extra-alveolar miniscrews for temporary skeletal anchorage

Soroush Basafa[1*], Johnny Liaw[2], Nikhilesh Vaid[3], Donald Ferguson[4]

Abstract

Objective: Temporary anchorage devices (TADs) have become integral in orthodontic treatments due to their ability to provide skeletal anchorage. This study aimed to evaluate the success rates of extra-alveolar miniscrews as a function of patient gender, placement location, and miniscrew size.

Methods: This retrospective cross-sectional study analyzed the dental records of 744 patients treated with TADs from 2016 to 2018. A total of 2,619 miniscrews of three different sizes (2×12 mm, 2×10 mm, and 1.4×8 mm) were inserted in five locations: the palate, mandibular buccal shelf, infrazygomatic crest, anterior maxilla, and anterior mandible. Success was defined as stability throughout treatment, while TADs that had to be removed, replaced or repositioned were regarded as failures. Statistical analyses included chi-square, ANOVA, and post hoc Tukey's tests. P-value<0.05 was considered statistically significant.

Results: The overall success rate was 79.3%. There was a significant association between the area of miniscrew insertion and TAD success rate (P<0.001). The highest success rate was observed in the palate (97.1%), followed by the mandibular buccal shelf (94.4%). The lowest success rate was observed in the infrazygomatic crest (73.8%). The 2×10 mm miniscrew size showed the highest success rate (87.6%), whereas 2×12 mm exhibited the lowest (75.4%).

Conclusions: Miniscrew success was significantly affected by the placement area, and the screw length and size. Palate and mandibular buccal shelf sites provided superior stability, and the 2×10 mm miniscrews provided the most successful results. These findings can aid orthodontists in TAD selection and treatment planning to achieve optimum outcomes.

Keywords: Bone screws, Treatment outcome, Orthodontic anchorage, Success rate, Orthodontic treatment, Miniscrew

Introduction

Achieving adequate anchorage is a critical aspect of successful orthodontic treatment. Precisely managing orthodontic anchorage is necessary to mitigate undesirable tooth movements (1). Orthodontic anchorage is attainable through extra- and intraoral sources (1, 2). The teeth, alveolar, cortical and basal jaw bones as well as the musculature can serve as intraoral sources, whereas extraoral anchorage can be established from the cranium, and facial and cervical bones (1).

Conventional anchorage systems highly depend on patient compliance, therefore the possibility of unintended anchorage loss can significantly jeopardize the treatment outcomes and increase the risk of failure (3). Temporary anchorage devices (TADs) were introduced to overcome this issue and offer the clinician an immediate source of skeletal anchorage for accomplishing a variety of tooth movements (4). TAD-mediated anchorage has become increasingly popular over the past decades due to its versatility, easy insertion, and minimally invasive nature (5, 6). Kanomi was the first to report applying miniscrew implants for anchorage mechanics in 1997 (7).

[1] European University College, DHCC, Dubai, UAE.
[2] Department of Orthodontics, National Taiwan University & Hospital, Taipei, Taiwan.
[3] Department of Orthodontics, Y.M.T Dental College & Hospital, Mumbai, India.
[4] Department of Orthodontics, European University College, DHCC, Dubai, UAE.

*Corresponding Author: Soroush Basafa
Email: S_basafa86@yahoo.com

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TADs are available in the form of mini-implants, mini-screws, mini-plates and onplants (8). Miniscrews are currently the most commonly used TADs and include interradicular miniscrews or extra-alveolar miniscrews inserted into the mandibular buccal shelf, infra-zygomatic crest or palate (9, 10). Using miniscrews for absolute anchorage has been able to facilitate different orthodontic purposes such as full arch retraction, correcting severe crowding or incisor protrusion, and treating skeletal discrepancies without requiring tooth extraction or orthognathic surgery (11-14).

Despite the advantages and increasing use of miniscrew anchorage, using these TADs has an inherent risk of failure, which can occur during insertion or after orthodontic loading (15, 16). This should be taken into consideration while using miniscrew-enhanced anchorage in orthodontic practice (13). Therefore, gaining knowledge of the factors that can influence miniscrew success/failure rates is of utmost importance. Several factors have been suggested to affect miniscrew success rates. Host-related factors include age, smoking, oral hygiene, amount of keratinized tissue, cortical bone thickness and bone density in the insertion site (17, 18). Technical factors include length, diameter, taper and shape of the screw; insertion angle, torque, and insertion modality (self-drilling or self-tapping) of the screw; and duration, amount and direction of orthodontic loading (18-22).

Bone quality has been recognized as a crucial determining factor for the success of miniscrew-mediated anchorage because these TADs are retained by mechanical locking in the cortical bone rather than osseointegration (23).

This study aimed to evaluate the stability of extra-alveolar mini-screws used for orthodontic anchorage as a function of location and mini-screw size in maxillary and mandibular regions. The null hypothesis stated that the success rate of miniscrews is not influenced by differences in screw size (diameter and length) or the area of placement.

Materials and methods

Study design and sample size

In this cross-sectional study, the dental records of patients were retrieved from the archives of a private orthodontic office. Patients underwent orthodontic treatment from January 2016 to January 2018. The patient's documents were retrospectively reviewed to include those who received extra-alveolar miniscrew anchorage. Written informed consent was waived due to the study's retrospective design. All mini-screws were placed and assessed by the same practitioner (DF) with over 15 years of clinical experience. The inserted mini-screws included three sizes by diameter and length, i.e. 2x12 mm, 2x10 mm or 1.4x8 mm. All mini-screws were made of stainless steel and manufactured by Bio-Ray, A-1, Taiwan. All TADs were self-drilling and placed under topical anesthesia or local infiltration and without elevation of a periosteal flap. Miniscrews were divided into five groups based on placement location: anterior maxilla and mandible, mandibular buccal shelf, infrazygomatic crest and the palate.

Study procedure

The orthodontist used a similar protocol for the insertion of all TADs. All posterior miniscrews were placed sub-apically as parallel as possible to the mandibular and maxillary first and second molar roots (extra-alveolar approach). Maxillary and mandibular anterior screws were inserted sub-apically avoiding root contact. The insertion points for palatal miniscrews were interdental between maxillary first and second molars or between second premolars and first molars. The direction of insertion was about 60 degrees oblique to the occlusal plane. A sharp dental explorer was used for sounding through the soft tissue to bone at the desired TAD site. The anatomic site for miniscrew placement was within the attached gingiva, at or near the mucogingival junction. After installation, the screw head was above the level of the soft tissue and the endosseous portion had approximately 5 mm of bone engagement.

All mini-screws were immediately loaded using pre-stretched elastomeric chains (Ormco Generation II Power Chain; Ormco, Glendora, CA, USA) to deliver a relatively uniform force. Force varied from 8 to 14 ounces (227 -397 gr) being proportional to the perceived density of the bone when screwing the miniscrew. According to the type of insertion (clockwise), all forces also were applied in a clockwise direction. The patients were instructed in oral hygiene procedures to control inflammation. The pre-stretched power chains were replaced every 4 weeks.

After placement, the initial stability of the miniscrew was checked by the clinician to ensure there were no signs of mobility. At subsequent clinical appointments, each miniscrew was checked for mobility. If the miniscrew was either removed or replaced because of mobility, it was recorded as "failed". The number of lost or replaced miniscrews was recorded concerning the patient's gender, insertion site and screw size. The

Table 1. The association between the success rate (percent) of miniscrews and patient gender

	Success (Number)	Failure (Number)	Success rate (%)
Female	1675	415	80.1
Male	403	126	76.2
Overall	2078	541	79.3
P-value	0.044		

duration of TAD use was defined as the interval between initial TAD placement and the end of orthodontic treatment and was recorded in months.

Statistical analysis

Data were subjected to statistical analysis using SPSS 15.01 software (SPSS Inc., Chicago, Il, USA). The association between the TAD success rate and various variables such as patient gender, area of placement and some miniscrew-related factors, i.e., diameter, length and size (length × diameter) were assessed using the chi-square test. One-way analysis of variance (ANOVA) was used to compare the average duration of TAD use between different locations, followed by post hoc Tukey's test for pairwise comparison. A P-value less than 0.05 was considered statistically significant.

Results

The sample included 744 patients, comprising 152 males and 592 females, treated with extra-alveolar mini-screws. Patients had a mean age of 25.7±2.1 years and were in the age range of 10-59 years. A total of 2,619 mini-screws were inserted and subsequently evaluated. Overall, 541 miniscrew failures were observed within the sample, resulting in a 79.3% success rate. As displayed in Table 1, a total of 529 and 2090 miniscrews were used for treating male and female patients, respectively. Miniscrew success rate was significantly higher in female patients (80.1%) compared to males (76.2%) (P=0.044).

Table 2 presents the TAD success rates according to different areas of placement. The highest TAD success rates were observed in the palate, mandibular buccal shelf, anterior mandible, anterior maxilla and infrazygomatic crest, in descending order. The palate was the most successful site for miniscrew placement with a success rate of 97.1%. The lowest success rate was observed in the infrazygomatic crest (73.8%). According to the chi-square test, there was a statistically significant association between TAD success rate and the area of placement (P<0.001).

Table 3 displays the association between the TAD success rate and some miniscrew-related parameters. There was no statistically significant relationship between the success rate of the miniscrew and its diameter (1.4 or 2 mm) (P=0.10). However, there was a statistically significant difference between the success rate of miniscrews with different lengths (8, 10 or 12) (P<0.001) The 10 mm length caused the highest success rate (87.6%) and the 12 mm showed the lowest (75.4%). Moreover, 2×10 mm miniscrews displayed the highest success rate (87.6%) followed by 1.4×8 mm (84.6%) and 2×12 mm (75.4%) miniscrews (P<0.001).

The mean duration of TAD use in different areas is presented in Table 4. The mean duration of TAD use was 17.2 ± 9.7 months. One-way ANOVA revealed that the average duration of TAD use significantly varied between different locations (P<0.001). Miniscrews inserted into the posterior maxilla showed the longest

Table 2. The association between the success rate of miniscrews and the area of placement

Location	Success (N)	Failure (N)	Success rate (%)
Infrazygomatic crest	1211	430	73.8%
Anterior maxilla	325	78	80.6%
Mandibular buccal shelf	272	16	94.4%
Anterior mandible	170	14	92.4%
Palate	100	3	97.1%
P-value	<0.001		

Table 3. The association between the success rate of miniscrews and screw diameter, length, and size (diameter × length)

Miniscrew-related factors		Success (N)	Failure (N)	Success rate (%)	P-value
Diameter (mm)	1.4	121	22	84.6	0.109
	2	1957	519	79.0	
Length (mm)	8	121	22	84.6	<0.001
	10	650	92	87.6	
	12	1307	472	75.4	
Miniscrew size (mm)	1.4×8	121	22	84.6	<0.001
	2×10	650	92	87.6	
	2×12	1307	427	75.4	

duration (18.54 ± 10.2 months). Pairwise comparisons revealed that the duration of TAD use in the infrazygomatic crest region was significantly longer than that of the miniscrews placed in the anterior maxilla, mandibular buccal shelf and anterior mandible (P<0.05).

Discussion

The present study evaluated the success rates of extra-alveolar miniscrews for achieving temporary skeletal anchorage. The literature identifies three primary factors influencing TAD success rates: patient-related factors, TAD characteristics, and the practitioner's level of expertise (24-26). In this study, the variable associated with the operator was controlled by evaluating the success rates of extra-alveolar TADs placed by one experienced orthodontist. The association between TAD success rate and patient gender, area of placement, and some miniscrew-related parameters, i.e. size, diameter and length, were assessed.

Intraradicular and extra-alveolar miniscrews are widely used in orthodontics to provide absolute anchorage for various tooth movements. Intraradicular miniscrews, are minimally invasive and mainly used for molar distalization and intrusion but are limited by anatomical constraints and the risk of root damage (27). In contrast, extra-alveolar miniscrews, positioned in areas such as the infrazygomatic crest or mandibular buccal shelf, offer broader applications, including total arch retraction, molar protraction, and occlusal plane control, while minimizing the risk of root damage (28, 29).

The overall success rate of miniscrews was 79.3% in this study. It is important to note that success/failure rate in the present study was determined by evaluating the TADs from insertion until the end of orthodontic treatment, which averaged 17.2 ± 9.7 months. Other studies have determined success/failure rates over shorter observation spans (10, 19).

In the present study, miniscrew-enhanced anchorage was significantly more successful in female patients compared to males (P=0.044). This was in contrast to the results of studies by Merati et al. (6), Mohammadi et al. (30) and Jing et al. (31), which did not report any significant association between gender and miniscrew success rates.

In this study, miniscrews were inserted in five different locations, i.e., the infrazygomatic crest, mandibular buccal shelf, anterior maxilla and mandible, and palate. There was a statistically significant association between TAD success and the area of placement. The highest and lowest TAD success rates were observed in the palate (97.1%) and infrazygomatic crest (73.8%), respectively. In contrast to the findings of the present study, Merati et al. (6) did not report any significant differences between the success rates of inter-radicular miniscrews inserted in different areas. However, the cited authors

Table 4. Duration of miniscrew use (months) according to the area of placement

Location	Duration (Months)	
	Mean	Standard deviation
Infrazygomatic crest	18.54	10.2[a]
Anterior maxilla	14.73	8.6[b]
Mandibular buccal shelf	14.53	7.0[b]
Anterior mandible	15.39	7.3[b]
Palate	16.53	11.8[a,b]
Overall	17.2	9.7
P-value	<0.001	

* Different lowercase superscript letters denote statistically significant differences between groups at P<0.05.

only evaluated TADs inserted in the upper jaw, i.e. in the buccal and palatal aspects of the anterior and posterior maxilla, whereas the present study compared success rates of extra-alveolar miniscrews inserted in both jaws. Chen et al. (32) investigated all influential factors affecting the failure rate of miniscrews and miniplates used as TADs. They did not find any significant association between TAD failure rates and their position (posterior or anterior segment) or location (upper or lower jaw). This discrepancy may be explained by the fact that the mentioned study evaluated an overall TAD failure rate for both miniscrews and miniplates, whereas in the present study, only extra-alveolar miniscrews were assessed.

According to the outcomes of this study, the palate was the most successful site for miniscrew insertion, demonstrating a success rate of 97.1%. This was in line with the findings reported by Xin et al (33), indicating that miniscrews in the palatal region showed lower progressive susceptibility to failure compared to those placed in posterior areas like the retromaxillary or retromandibular regions. The palate provides a thicker and denser bone structure, contributing to the enhanced stability and success rate of miniscrews placed in this site.

Miniscrews inserted in the mandibular buccal shelf (94.4%) exhibited higher success rates compared to those placed in the infrazygomatic crest (73.8%). This discrepancy may be attributed to differences in bone density between these regions. Chang et al. (34) also reported a 92.8% success rate for the mandibular buccal shelf miniscrews. This value was similar to the 94.4% success rate observed in the current study.

Three different miniscrew sizes, i.e. 1.4×8 mm, 2×10 mm and 2×12 mm, were used and compared in this study. The findings indicated a statistically significant association between miniscrew size and success rate, with the highest success rate for 2×10 mm miniscrews (87.6%). On the other hand, the 2×12 mm miniscrews exhibited the lowest success rate (75.4%), whereas the success rate of 1.4×8 mm miniscrews was 84.6%. A randomized clinical trial by Sarul et al. (35) compared the long-term stability of 1.5×8 mm and 2×10 mm titanium miniscrews inserted in the mandibular buccal shelf. The miniscrews were considered stable if they provided anchorage until complete distalization of the mandibular molars was achieved. Their findings revealed a significantly higher success rate for the larger 2×10 mm miniscrews compared to the 1.5×8 mm miniscrews, similar to the findings of this study.

There was no significant association between miniscrew diameter and TAD success rate. However, the length of the miniscrew was proven to have a significant effect on the TAD success rate. This finding aligns with a previous study by Uesugi et al. (36) that demonstrated a significant association between miniscrew length and success/failure rate after the insertion of TADs in the posterior maxilla. Similarly, Sarul et al. (37) noted a significant relationship between miniscrew length and its success rate. It is worth mentioning that in the mentioned studies (36, 37), 8 mm miniscrews demonstrated greater stability and higher success rates compared to 6 mm miniscrews, suggesting that longer miniscrews were more successful. In the present study, the highest TAD success rates were observed in 10 mm (87.6%), 8 mm (84.6%) and 12 mm (75.4%) miniscrews, in descending order. This suggests that increasing the miniscrew length from 8 mm to 10 mm improves the success rate, but further increasing the length to 12 mm diminishes it, indicating that longer lengths do not consistently yield higher success rates.

The duration of TAD use varied by area of placement, with the infrazygomatic crest showing the longest mean duration (18.54 ± 10.2 months). In contrast, shorter durations were observed in the anterior maxilla (14.73 ± 8.6 months), mandibular buccal shelf (14.53 ± 7.0 months), and anterior mandible (15.39 ± 7.3 months). This higher duration of TAD use in the infrazygomatic crest may be related to the type of tooth movement (for example arch distalization) which may require longer force application compared to anterior tooth movement.

One limitation of the present study was its retrospective design. The data were obtained from a single clinician, which may limit the generalizability of the results. Furthermore, the impact of other factors such as bone density, cortical thickness, miniscrew design and orthodontic loading were not assessed in the present study. We recommend that future studies assess TAD survival rates and examine other clinical variables, such as the occurrence of soft tissue inflammation around the TAD.

Conclusions

Under the conditions used in this study:

1. The overall success rate of extra-alveolar miniscrews was 79.3%. The success rate by TAD position varied from 97.1% (palate) to 73.8% (infrazygomatic crest). There was a significant association between the area of placement and

miniscrew success rate. The success rate was significantly greater in female than male patients.

2. There was a significant association between miniscrew size and TAD success rate. The 2×10 mm miniscrews were the most successful TADs, whereas the 2×12 mm miniscrews exhibited the lowest success rate (75.4%).

Acknowledgments

There is nothing to declare.

Conflict of interest

The author denies any conflicts of interest related to this study.

Authors' contributions

N.V. conceived and designed the study. S.B. and J.L. collected the data. D.F. performed statistical analysis and data interpretation. S.B. and D.F. prepared the manuscript. All authors read and approved the final manuscript.

Ethical approval

Written informed consent was waived due to the study's retrospective design.

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