

Review Article

Revisiting the Complications of Orthodontic Miniscrew

Van Mai Truong ¹, Soyeon Kim ¹, Jaehoon Kim ¹, Joo Won Lee ¹,
and Young-Seok Park ^{1,2}

¹Department of Oral Anatomy and Dental Research Institute, School of Dentistry, Seoul National University, Seoul 03080, Republic of Korea

²Head of Center for Future Dentistry, School of Dentistry, Seoul National University, Seoul 03080, Republic of Korea

Correspondence should be addressed to Young-Seok Park; ayoayo7@snu.ac.kr

Received 31 May 2022; Accepted 20 July 2022; Published 1 August 2022

Academic Editor: Fernanda Faot

Copyright © 2022 Van Mai Truong et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Miniscrew has been used widely as an effective orthodontic anchorage with reliable stationary quality, ease of insertion and removal techniques, immediate or early loading, flexibility in site insertion, less trauma, minimal patient cooperation, and lower price. Nonetheless, it is not free of complications, and they could impact not only the miniscrew success rate but also patients' oral health. In this article, literature was searched and reviewed electronically as well as manually to evaluate the complications of orthodontic miniscrew. The selected articles are analyzed and subcategorized into complications during and after insertion, under loading, and during and after removal along with treatment if needed according to the time. In addition, the noteworthy associated factors such as the insertion and removal procedures, characteristics of both regional and local anatomic structures, and features of the miniscrew itself that play a significant role in the performance of miniscrews are also discussed based on literature evidence. Clinicians should notice these complications and their related factors to make a proper treatment plan with better outcomes.

1. Introduction

Orthodontic anchorage is a prerequisite for the success of orthodontic treatment. Various types of anchorages are available, composing onplants, palatal plates, miniplates, and miniscrews [1]. Among them, miniscrews have been used more widely for orthodontic anchorage reinforcement due to good stationary quality, various insertion sites, simple placement or removal procedures, light tissue invasion, immediate or early loading allowance, minimal patient compliance, and low cost [2–4]. Miniscrews have been proved to provide reliable anchorage and placed in numerous clinical applications such as deep bite correction, space closer, midline correction, extrusion, intrusion, distalization, mesialization, and en-masse retraction [2] with high success rate [5]; in addition, the uses of miniscrew have widened the scope of nonsurgical orthodontic therapy [6]. Moreover, it was shown that miniscrews could facilitate more favorable outcomes compared with conventional methods [7, 8].

Nonetheless, complications could occur not only during and after insertion but also under loading, during, and after removal. It is necessary for clinicians to comprehensively understand its complications and related factors to minimize the failure rate.

2. Complications during Insertion

2.1. Root Contact. The insertion of orthodontic miniscrews in interradicular regions could lead to iatrogenic root damage. Among the complications, its outcome could be considered the most serious for the patient's dental health [9]. Potential complications of root injury include loss of tooth pulp sensibility, root resorption, root fracture, osteosclerosis, and dentoalveolar ankylosis [10, 11].

The periradicular lesion as a consequence of root proximity could be successfully treated with endodontic treatment and apical surgery with mineral trioxide aggregate [12–14]. Although it was possible to be repaired successfully,

the need for particular attention should be highlighted during miniscrew placement to decrease the risk of root damage. Increased failure rates of miniscrew placement were detected among those contacting adjacent roots [15]. It was also found that root damage was a crucial risk factor for miniscrew failure [16].

A perforated root has a capability of spontaneous repairing and regenerating after immediate removal of the offending miniscrew and additional stimulation for an adequate period, and orthodontic therapy could be finished without unfavorable symptoms [17–19]. The injured root could be monitored for possible revitalization and regeneration rather than performing endodontic therapy instantaneously [19]. Nevertheless, this could occur only when root damage caused by miniscrew placement is limited to the cementum or the dentin without inflammatory infiltrate or pulpal injury [20]. Cases that miniscrews invaded the pulp were less feasible to archive absolute repair of the periodontal tissues [9]. On the other hand, it was reported that insertion of the miniscrew into the periodontal ligament even less than 1 mm could cause external root resorption [21].

Insertion torque with root contact was proved to be higher than those without and in agreement with many studies [22]. One study showed that the average placement torques in contact cases were twice higher than those in noncontact cases [20]. For that reason, increased resistance during miniscrew insertion was recognized as an indicator of root contact [20]. Nonetheless, bone density might be diverse among individuals and placement locations. Besides, even under topical anesthesia, when the miniscrew started to contact the periodontal ligament, increased sensation could be felt by the patient [23, 24]. Once doubtful symptoms of root proximity are noticed, taking periapical radiography and cone-beam computed tomography is recommended to approve and assess the root status [19].

For the anterior region, the area with the greatest amount of interradicular bone for miniscrew placement was between the lateral incisor and the first premolar [25]. For the posterior area, the region between the second premolar and the second molar was suggested to be the safest zone [26]. In the maxilla, the best option was from the second premolar to the first molar, from 6 to 8 mm from the cervical line [27]. In the mandible, the most favorable zone was from the first molar to the second molar, below 5 mm from the cervical line [27].

It is important to make a careful plan for miniscrew insertion to minimize the potential of root damage [18]. The application of surgical guides, fabricated using cone-beam computed tomography (CBCT) images, could be considered a technique for more accurate orthodontic miniscrew placement adjacent to important anatomic structures [28–31].

2.2. Perforation of Maxillary Sinus and Nasal Cavity Floor.

During orthodontic miniscrew installation, perforation into the nasal cavities and maxillary sinuses has been reported [32–35]. Infrazygomatic crest anchorage has been applied successfully for anterior retraction, space closure, posterior intrusion, and molar and maxillary dental arch distalization

[32]. This region may be particularly amenable to miniscrew insertion due to the two cortical layers that will ensure primary stability if a miniscrew with proper length could be fixed bicortically [34]. Bicortical miniscrews provide higher anchorage resistance, lower cortical bone stress, and better stability in comparison with monocortical miniscrews [3].

In the palate, distance to the nasal cavity and maxillary sinus was greatest in the region mesial to the first premolar and then the distance started to decrease significantly [36]. In the buccal area, perpendicular insertion was safe with minimal risk of sinus or nasal cavity injury, while oblique placement increased the possibility of sinus and Schneiderian membrane penetration [36–38].

The response of the maxillary sinus to perforation by dental implants has been assessed; a simple perforation smaller than 2 mm may heal spontaneously without complications [10]. However, in the case of perforation by orthodontic miniscrews, this might not apply, since the implant size, loading pattern, surrounding bone characteristics, and blood flow may be different compared to dental implants [32]. Even though in some studies miniscrew removal and interruption of orthodontic therapy after perforation were not operated without complications, it may be a risk factor for miniscrew failure [33]. A sinus perforation at a depth not exceeding 1.5 mm did not seem to affect miniscrew anchorage [33]. However, a study reported that nasal floor perforation caused oronasal fistula development during wound healing and surgery had to be performed to close it after miniscrew removal [35].

Therefore, clinicians should consider primary stability with sinus health status at the same time. Infrazygomatic crest miniscrew anchorage was recommended to be bicortical fixed with penetration depth limit within 1 mm [32]. To achieve it, the infrazygomatic crest region should be fully analyzed using CBCT, considering individual differences; virtual miniscrew insertion in the CBCT scans was also advisable for deciding miniscrew size and placement angulation [32].

2.3. Cortical Bone Damage. Extensive osseous microdamage during insertion of orthodontic miniscrew may reduce the stability of immediately loaded miniscrews due to the bone remodeling processes initiated by microdamage [39]. Large diameter miniscrews and overtightening through deep insertion might lead to more significant microdamage to the cortical bone [39, 40]. Nevertheless, miniscrews with too small diameters could raise the potential of miniscrew fracture during placement and mobility of the miniscrews when orthodontic force is applied due to the low resistance to removal torque. Miniscrews with diameters of 1.5 or 1.6 mm were recommended as a compromise between the physical properties of miniscrews and microdamage in the cortical bone [40].

Pilot drilling might be an effective solution to reduce microdamage during insertion [41, 42]. After pilot drilling, both the miniscrew diameter and the insertion site (mandible vs maxilla) had no significant effect on the amount of microdamage around the miniscrew [41]. Moreover, to

prevent excessive microdamage, large diameter and cylindrical miniscrews should be avoided [42].

Regarding the insertion technique, more serious microdamage in the cortical bones was observed in both maxilla and mandible by the self-drilling placement technique in comparison with the pre-drilling (self-tapping) one [43]. Besides, the cortical bone thickness was shown to have a significant influence on the amount of microdamage created instantly after placement. There was a statistically significant positive association between cortical bone thickness and the amount of microdamage [44]. It was suggested that practitioners should take into account the thickness of cortical bone at the placement site, because reducing cortical bone thickness will likely decrease the amount of microdamage created during insertion [44].

2.4. Miniscrew Fracture. Increased torque placement could cause miniscrew bending or fracture that not only affects the miniscrew stability but may also requires surgical intervention. Miniscrew fracture has been reported and caused a sinus tract, and the fractured tips had to be removed surgically [13, 45].

Miniscrews from different manufacturers have different designs and morphology; outside and internal diameters, the ratio of these two diameters, and milling in miniscrew apical region were the factors that decide the fracture torque resistance [46]. Fracture most likely happens in the cervical part of the miniscrew because of mechanical stress focusing at this point [45]. Stress distribution on the miniscrew surfaces and the adjacent bone in force application was proved to be related to insertion depth and angulation [47, 48]. Miniscrew inclined insertion with upward traction was recommended to be the safest option to prevent miniscrew failure and fracture [47].

This complication could be prevented or limited by choosing the appropriate placement torque with a suggested range from 5 to 10 N.cm [49, 50]. In addition, for self-drilling miniscrew, a pilot hole should be applied beforehand to prevent excessive torque [50].

3. Complications after Insertion

Installation of miniscrews may cause pain and discomfort [35, 51–56]. Pain intensity and discomfort were not greater than other orthodontic procedures, and some authors reported that patients preferred miniscrews to tooth extraction [51–53]. Therefore, patients were willing to adopt the new orthodontic treatment, and this did not negatively affect the final general satisfaction with the treatment [52, 55]. However, insertion with extra-alveolar bone miniscrews and flap surgery was shown to cause more pain than that of the smaller miniscrew and nonflap surgery [56, 57].

Prolongation of pain most likely happened in the anterior teeth [35]. This might be caused by the interference fit of the palatal miniscrew created after placement [35]. One case in which pain lasted until the miniscrew got loose was reported; this might be triggered by compressing or contacting the incisal nerve [35]. Although permanent nerve injury after miniscrew installation has not been described in the

literature, precautions should be taken to avoid nerve involvement.

Secondary bleeding after miniscrew insertion may also happen. Prolonged bleeding could be stopped by compression. If this method does not work, clinicians can constrict the bleeding vessel or use electrocautery to stop bleeding [35].

4. Complications under Loading

4.1. Stationary Anchorage Failure. Many risk factors could affect the stability of miniscrew: patient-related (age and sex), miniscrew-related (diameter, length, and design), location-related (thickness of cortical bone, density of bone, thickness and type of soft tissue, and insertion site), and clinical procedure-related (pre-drilling/self-drilling, pilot hole, and method of loading). The affections of these factors were significantly different between studies.

Among risk factors from patients, the association between miniscrew failure and age was not consistent. Some studies showed no relationship between age and failure [58–60]; whereas others found that age could affect the miniscrew stability since there was poorer quality and higher bone turnover rate in growing patients compared to adults, affecting optimal mechanical miniscrew stability in adolescents [61–65]. Therefore, more attention should be taken to the miniscrew placement in younger patients. The affection of sex was also found to be controversial. While some studies reported that there were no statistical differences [58–60, 65], others reported that males had a higher success rate due to higher bone density [59, 62].

Regarding miniscrew characteristics, an increase in miniscrew diameter and length could reinforce the initial stability [65–67]. Nonetheless, the proximity of anatomical structures should be considered. A study reported that miniscrews of 1.2-mm diameter and at least 8-mm length were favorable for the reason that they were stable and limited the probability of root injury [68]. In another study, higher success rates were also found with the same length of miniscrews (≥ 8 mm), but slightly higher diameter (>1.4 mm) [65]. Miniscrew stability may also vary with its design, and a study suggested that a conical miniscrew design would provide greater primary stability than a cylindrical miniscrew type [69].

The success of orthodontic miniscrews may be affected by various location-related factors. Miniscrew stability was positively associated with the cortical bone thickness of the insertion site [66, 70, 71]. Motoyoshi et al. reported that a cortical bone thickness threshold of 1 mm increased the miniscrew success rate [72]. Bone density may also play a role in miniscrew failure; with the same length of miniscrew, good anchorage resistance was obtained only in bone with optimum density [73]. However, another study proved that there were no established associations between bone density and miniscrew success rate [74, 75]. In addition, one study showed that miniscrew stability was associated linearly with insertion depth, extrabony miniscrew length may also be a determinant of miniscrew stability, and it was suggested that insertion sites should be selected so that mucosa there is as thin as possible [76]. This was in an agreement with another

study that the thickness of the soft tissues was an important factor in the success of orthodontic miniscrew; due to soft tissue thickness variation, clinicians should consider before selecting a miniscrew [77]. Moreover, placement in attached gingiva seemed to be more favorable to achieving higher success of miniscrew compared with insertion in movable mucosa [67, 78]. Maxilla placement of miniscrews was more successful than mandible [61, 65, 78, 79] due to more keratinized tissue, less challenging surgical technique, greater vascularization of the maxilla or greater bone overheating during drilling [78], and irritation during chewing of the mandibular [79]. Meanwhile, another study concluded that significant differences in the success rates among receptor sites were found only with pre-drilling miniscrews; it was suggested that the insertion procedure might play a certain role in the success rate of miniscrew [80].

Self-drilling miniscrews have been reported to reduce clinical time, bone damage, and patient discomfort compared with pre-drilling miniscrews [81]. A systematic review suggested that there were no differences between the success rates of pre-drilling and self-drilling miniscrews [82]. With pre-drilling miniscrew, a pre-drilled hole is required. The relationship between the diameter of the pilot hole and miniscrew stability was summarized as follows: the larger pilot hole compared to miniscrew diameter is, the lower the primary stability of miniscrew is; the smaller pilot hole compared to miniscrew diameter is, the more potentially miniscrew will fracture [83]. To have proper insertion torque and to prevent miniscrew fracture as well as extreme bone stress, there should be an ideal combination of pre-drilling pilot and miniscrew diameter; it was recommended that the drill diameter should be 0.5 mm smaller than that of miniscrew [84].

Inadequate primary stability might be also caused by overwinding during miniscrew installation. Open flap technique was performed for better vision and to prevent overwinding. Nonetheless, a necrotic mucosa of miniscrew was observed only in cases with flap surgery [35]. In addition, the success rates presented for flap and flapless procedures were not homogeneous among studies [67].

Applying low-level laser was shown to increase the stability of miniscrew and peri-screw bone formation [85]. In addition, a small diameter decortication using Er:YAG laser might produce better primary stability in comparison with using a drill; thus, it could be used as an alternative [86]. However, additional studies should be employed to confirm the results.

There has been controversy regarding the waiting period between miniscrew placement and orthodontic loading. On the other hand, immediate loading was shown to give favorable contact with the adjacent bone and not affect miniscrew anchorage [87–89]. Even though immediate or early loading of miniscrews can be applied, the limit of force at 200 cN was recommended [68]. The direction of the orthodontic force may also affect the primary stability of miniscrews [90]. Dislodgement of miniscrew occurred most frequently in the first 2 months and mostly within the first 4 months [60]. In addition, clini-

cians' experience and skill also play an important role in the success rate of miniscrew [63, 91].

Unfortunately, the diversity of analyzed factors of miniscrew anchorage may lead to bias; for that reason, homogenous groups of patients are necessary for reliable assessment. The analyzed factors should be treated with caution due to the different methodologies employed in different studies.

4.2. Miniscrew Displacement. Although miniscrews have been affirmed to provide good stationary quality, many studies confirmed that there was a remarkable secondary displacement of the miniscrew under orthodontic loading over time [89, 92–95]. However, this displacement did not appear to affect the clinical performance of miniscrews [93, 95].

The amount of movement is clinically considered since there is potential to interfere with vital structures such as foramen, nerves, blood vessels, or dental roots. The safe zone between miniscrew and dental root varied among studies, extending from 1.5 mm to 2 mm for prevention [89, 92]. However, one study reported that the mean secondary dislocation was from 0 to 2.7 mm for entire miniscrews; also, controlled tipping and bodily movements were the most common [93]. For safety, further research should be investigated for predicting the optimal zone.

Bone mineral density rather than cortical bone thickness was the key factor in controlling the primary migration of miniscrew under functional orthodontic loading [94]. Additionally, both pre-drilling and self-drilling miniscrews showed displacement under loading, and the quantity of dislocation was related to the period of loading time without noticeable mobility or loosening [95].

4.3. Traumatic Soft Tissue Lesion and Soft Tissue Coverage. Traumatic soft tissue lesions could happen in the form of aphthous ulcerations or canker sores in alveolar, buccal, labial mucosa, or frenulum [10, 96]. However, these injuries are self-limiting and able to heal without further complications. Using healing abutment, wax pellet, and elastic separator over the head of miniscrew, with daily use of chlorhexidine, was performed for ulceration prevention and patient comfort improvement. The appearance of a traumatic lesion was not considered a direct risk factor for the anchorage of miniscrew; however, it may be a sign of more severe soft tissue inflammation [10].

Light-cured temporary filling material was used to cover the head of the miniscrew, and this is a simple method that was recommended for soft tissue trauma prevention [96]. However, using composite resin could make ligating to the miniscrew harder; furthermore, the contact between the composite resin and peri-screw tissue may cause allergy if the patient is sensitive to the components of the material [97]. Thus, an article suggested a modification method by placing an elastomeric separator around the head to maintain some space between the composite resin and the peri-screw tissue [97].

Overgrowth, defined as the partial or complete covering of the miniscrew head by soft tissue, was reported to be the most common complication in one study with no treatment

TABLE 1: Complications of miniscrew, their related factors, and treatment.

Complications	Related factors	Treatment	
During insertion	Root contact	(i) Interradicular region (ii) Damage location: cementum/dentin/pulp (iii) Insertion torque: increased resistance (iv) Increased sensation by patient	(i) Immediate removal (ii) Endodontic treatment/apical surgery
	Perforation of maxillary sinus and nasal cavity floor	(i) Infrazygomatic crest anchorage (ii) Perforation depth	(i) No treatment (ii) Miniscrew removal (iii) Surgery performed to close the perforation
During insertion	Cortical bone damage	(i) Large diameter miniscrew (ii) Overtightening (iii) Pilot drilling and insertion technique (self-drilling/pre-drilling) (iv) Cortical bone thickness	(i) No treatment
	Miniscrew fracture	(i) Designs and morphology of miniscrew (ii) Placement torque (iii) Insertion depth and angulation (iv) Pilot drilling and insertion technique	(i) Surgical intervention to remove the fractured tip
	Pain and discomfort	(i) Size of miniscrew (ii) Flap/nonflap surgery	(i) No treatment
After insertion	Secondary bleeding	(i) Unknown	(i) Compression (ii) Constrict the bleeding vessel (iii) Use electrocautery
	Stationary anchorage failure	(i) Age, sex (ii) Diameter, length, design of miniscrew (iii) Thickness of cortical bone, density of bone, thickness and type of soft tissue, insertion site (iv) Pre-drilling/self-drilling, pilot hole, method of loading	(i) Miniscrew removal (ii) Repositioning
Under loading	Miniscrew displacement	(i) Bone density and cortical bone thickness (ii) Period of loading time	(i) No treatment unless it affects the vital structures
	Traumatic soft tissue lesion	(i) Head of miniscrew	(i) No treatment
	Soft tissue coverage	(i) Insertion depth (ii) Length of miniscrew neck	(i) No treatment
	Peri-screw inflammation	(i) Insertion region (ii) Oral hygiene	(i) Control of infection (ii) Miniscrew removal (iii) Repositioning
During removal	Miniscrew fracture	(i) Removal torque (ii) Instrument used for removal (iii) Partial osseointegration (iv) Diameter and surface roughness of miniscrew	(i) Surgical intervention to remove the fractured part
	Soft tissue scarring	(i) Flat gingiva (ii) Buccal interdental insertion	(i) Scar removal by excising
After removal	Bone and root resorption	(i) Bone microdamage (ii) Miniscrew-assisted intrusion (iii) Intrusive force	(i) No treatment
	Alveolar bone exostoses	(i) Unknown	(i) Resective osseous surgery

needed. Although it did not bring serious complications but could cause time-consuming annoyance, this complication might be prevented by either decreasing the insertion depth or using miniscrews with longer necks. However, due to primary and long-term anchorage, miniscrews with longer necks may be preferable; besides, it is necessary for patients to maintain good oral hygiene [98].

4.4. Peri-screw Inflammation. Inflammation around the miniscrew was reported to occur in the regions of palate, buccal fold, and ascending ramus [45]. Peri-screw inflammation was associated with miniscrew failure [74, 99]. In patients with poor oral hygiene, inflammation can happen even if the placement procedure is operated carefully [45].

Presurgical and postsurgical oral hygiene was considered a critical factor to prevent peri-screw inflammation [45, 64, 100]. Patients need to have thorough oral care education, and professional cleaning may be also necessary for the orally exposed part of the miniscrews [101].

Miniscrews inserted in the buccal surface of the alveolar process and the alveolar mucosa had a greater chance to have inflammation [45, 102]. Control of infection is a fundamental factor to ensure the stability of the miniscrew [102]. Local disinfectants, antiseptic mouthwash, and careful brushing techniques were recommended for this purpose [45, 101]. In more severe cases, antibiotics [101] or miniscrew removal and repositioning in another site [102] may be needed, even though no stability loss was observed.

5. Complications during Removal

During removal, miniscrew fracture can happen if the torque is over the limit of the miniscrews [80]. For this reason, controlling the removal torque was recommended [103]. In addition, partial osseointegration surrounding miniscrews could be obtained after insertion, and fracture might not be avoided if it is the result of the strength of osseointegration [80]. Fracture of miniscrew during removal has been reported and had to be retrieved by surgery [35] which may lead to significant bone removal and potential risks for patients [80].

Even though it was reported that miniscrews could be removed with hand-operated drivers while controlling torque, using battery-operated drivers or other units which do not offer torque limitation in reverse mode was not advisable [103]. Besides, it may be a favorable method to use ultrasonic instruments for orthodontic miniscrew removal due to less bone loss and faster bone healing in comparison with using low-speed handpiece rotary instruments [104].

One study showed that applying sandblasting and acid etching for surface roughness did not improve the success rate but increased the removal torque significantly which may raise the risk of miniscrew fracture [105]. Moreover, a miniscrew with smaller diameters and made of ductile titanium alloy may also collaborate to increase the chance of miniscrew fracture during removal [80].

6. Complications after Removal

In general, orthodontic miniscrew removal is not considered a traumatic approach. However, after removal, there will be a temporary full-thickness defect through soft tissue and alveolar bone underneath, which is healed by secondary intention [106].

6.1. Soft Tissue Scarring. After orthodontic miniscrew removal, detectable soft tissue scarring may develop at a fairly high rate [106, 107]. Even though this scarring was only located at the site of placement and was not considered serious, it might give negative esthetic problems [106]. The scar tissues were excised successfully under local anesthesia, but further studies should be investigated for soft tissue healing improvement and visible scarring prevention [106].

Flat gingiva and buccal interdental gingival insertion are more likely to have scar formation [107]. Proper miniscrew placement torque values may limit the probability of not only negative tissue responses such as scar tissue formation but also micromotion [80].

6.2. Bone and Root Resorption. Excess microdamage created during miniscrew insertion may cause bone resorption [108]. In addition, based on the presently available evidence, miniscrew-assisted intrusion is a risk factor for orthodontically induced inflammatory root resorption; however, a variety of related characteristics (such as insertion site, intrusion site, duration, and magnitude of intrusive force) may have influence on the outcome [109]. It was believed that the magnitude of intrusive force was associated directly with the root resorption [110]. Nevertheless, due to methodological inconsistencies, it was challenging to quantitatively assess the results [109]. During this process, the application of photobiomodulation might have a possibility to lower the progression of root resorption, but it may also slightly lower intrusion distance and speed [111].

6.3. Alveolar Bone Exostoses. An alveolar bone exostosis is a localized, peripheral bone overgrowth with unknown pathogenesis; but the potential factors could be race, autosomal dominance, hyperfunctional masticatory, and nutrition [112]. Normally, for alveolar bone exostosis, the treatment will not be operated unless its size affects the periodontal tissue or causes pain and discomfort for patients [112]. Alveolar bone exostoses have been reported once in the literature as a complication of orthodontic miniscrew [113]. In this case, resective osseous surgery was performed, and orthodontic treatment was continued after one month without recurrence [113].

7. Conclusions

This article has focused on pointing up the complications of miniscrew and their related factors reported through the literature that are summarized in Table 1. It is suggested that clinicians should thoroughly understand the insertion and removal procedures and characteristics of both regional and local anatomic structures as well as features of the miniscrew itself to optimize the success rate. Attention should be given that there may be biases between studies due to the diversity of analyzed factors along with markedly heterogeneous protocols. Future studies are needed to address a standard protocol with homogeneity.

Data Availability

The data was obtained from PubMed database.

Conflicts of Interest

The authors declared no conflict of interest for this work.

Acknowledgments

This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2021R1I1A2048516, 70%) and the Korea Medical Device Development Fund grant funded by the Korea government (the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, and the Ministry of Food and Drug Safety) (Project Number: 1711134912, KMDF_PR_20200901_0002-01, 30%).

References

- [1] X. Zheng, Y. Sun, Y. Zhang, T. Cai, F. Sun, and J. Lin, "Implants for orthodontic anchorage: an overview," *Medicine*, vol. 97, no. 13, article e0232, 2018.
- [2] G. Jasoria, W. Shamim, S. Rathore, A. Kalra, M. Manchanda, and N. Jaggi, "Miniscrew implants as temporary anchorage devices in orthodontics: a comprehensive review," *The Journal of Contemporary Dental Practice*, vol. 14, no. 5, pp. 993–999, 2013.
- [3] B. T. Brettin, N. M. Grosland, F. Qian et al., "Bicortical vs monocortical orthodontic skeletal anchorage," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 134, no. 5, pp. 625–635, 2008.
- [4] H. Mohammed, K. Wafaie, M. Z. Rizk, M. Almuzian, R. Sosly, and D. R. Bearn, "Role of anatomical sites and correlated risk factors on the survival of orthodontic miniscrew implants: a systematic review and meta-analysis," *Progress in Orthodontics*, vol. 19, no. 1, p. 36, 2018.
- [5] D. M. Ramirez-Ossa, N. Escobar-Correa, M. A. Ramirez-Bustamante, and A. A. Agudelo-Suarez, "An umbrella review of the effectiveness of temporary anchorage devices and the factors that contribute to their success or failure," *The Journal of Evidence-Based Dental Practice*, vol. 20, no. 2, p. 101402, 2020.
- [6] S. H. Choi, J. Y. Jeon, K. J. Lee, and C. J. Hwang, "Clinical applications of miniscrews that broaden the scope of non-surgical orthodontic treatment," *Orthodontics & Craniofacial Research*, vol. 24, no. S1, pp. 48–58, 2021.
- [7] J. Antoszewska-Smith, M. Sarul, J. Lyczek, T. Konopka, and B. Kawala, "Effectiveness of orthodontic miniscrew implants in anchorage reinforcement during en-masse retraction: a systematic review and meta-analysis," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 151, no. 3, pp. 440–455, 2017.
- [8] Y. Liu, Z. J. Yang, J. Zhou et al., "Soft tissue changes in patients with dentoalveolar protrusion treated with maximum anchorage: a systematic review and meta-analysis," *The Journal of Evidence-Based Dental Practice*, vol. 19, no. 4, p. 101310, 2019.
- [9] M. Alves Jr., C. Baratieri, C. T. Mattos, M. T. Araujo, and L. C. Maia, "Root repair after contact with mini-implants: systematic review of the literature," *European Journal of Orthodontics*, vol. 35, no. 4, pp. 491–499, 2013.
- [10] N. D. Kravitz and B. Kusnoto, "Risks and complications of orthodontic miniscrews," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 131, no. 4, pp. S43–S51, 2007.
- [11] G. Gintautaitė, G. Kenstavičius, and A. Gaidytė, "Dental roots' and surrounding structures' response after contact with orthodontic mini implants: a systematic literature review," *Stomatologija*, vol. 20, no. 3, pp. 73–81, 2018.
- [12] K. Er, M. Bayram, and T. Tasdemir, "Root canal treatment of a periradicular lesion caused by unintentional root damage after orthodontic miniscrew placement: a case report," *International Endodontic Journal*, vol. 44, no. 12, pp. 1170–1175, 2011.
- [13] P. McCabe and C. Kavanagh, "Root perforation associated with the use of a miniscrew implant used for orthodontic anchorage: a case report," *International Endodontic Journal*, vol. 45, no. 7, pp. 678–688, 2012.
- [14] Y. C. Hwang and H. S. Hwang, "Surgical repair of root perforation caused by an orthodontic miniscrew implant," *American journal of orthodontics and dentofacial orthopedics*, vol. 139, no. 3, pp. 407–411, 2011.
- [15] Y. H. Chen, H. H. Chang, Y. J. Chen, D. Lee, H. H. Chiang, and C. C. J. Yao, "Root contact during insertion of miniscrews for orthodontic anchorage increases the failure rate: an animal study," *Clinical oral implants research*, vol. 19, no. 1, pp. 99–106, 2008.
- [16] S. Kuroda, K. Yamada, T. Deguchi, T. Hashimoto, H. M. Kyung, and T. Takano-Yamamoto, "Root proximity is a major factor for screw failure in orthodontic anchorage," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 131, no. 4, pp. S68–S73, 2007.
- [17] P. E. Chang, E. Kim, W. Jang, H. Y. Cho, and Y. J. Choi, "Spontaneous repair of iatrogenic root perforation by an orthodontic miniscrew: a case report," *Journal of the American Dental Association (1939)*, vol. 152, no. 3, pp. 234–239, 2021.
- [18] G. Lim, K. D. Kim, W. Park, B. Y. Jung, and N. S. Pang, "Endodontic and surgical treatment of root damage caused by orthodontic miniscrew placement," *Journal of Endodontia*, vol. 39, no. 8, pp. 1073–1077, 2013.
- [19] J. Y. Lee, P. S. Kim, C. Choi, and K. B. Kim, "Root repair and regeneration after miniscrew root damage," *Journal of the World Federation of Orthodontists*, vol. 5, no. 2, pp. 70–78, 2016.
- [20] C. E. Brisceno, P. E. Rossouw, R. Carrillo, R. Spears, and P. H. Buschang, "Healing of the roots and surrounding structures after intentional damage with miniscrew implants," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 135, no. 3, pp. 292–301, 2009.
- [21] K. I. Min, S. C. Kim, K. H. Kang et al., "Root proximity and cortical bone thickness effects on the success rate of orthodontic micro-implants using cone beam computed tomography," *The Angle Orthodontist*, vol. 82, no. 6, pp. 1014–1021, 2012.
- [22] R. M. Meursing Reynders, L. Ladu, L. Ronchi et al., "Insertion torque recordings for the diagnosis of contact between orthodontic mini-implants and dental roots: a systematic review," *Systematic reviews*, vol. 5, no. 1, pp. 1–9, 2016.
- [23] E. Y. Suzuki and B. Buranastidporn, "An adjustable surgical guide for miniscrew placement," *Journal of Clinical Orthodontics*, vol. 39, no. 10, pp. 588–590, 2005.
- [24] H. M. Kyung, H. S. Park, S. M. Bae, J. H. Sung, and I. B. Kim, "Development of orthodontic micro-implants for intraoral anchorage," *Journal of Clinical Orthodontics*, vol. 37, no. 6, pp. 321–8; quiz 314, 2003, quiz 14.

- [25] S. Alsamak, S. Psomiadis, and N. Gkantidis, "Positional guidelines for orthodontic mini-implant placement in the anterior alveolar region: a systematic review," *The International Journal of Oral & Maxillofacial Implants*, vol. 28, no. 2, pp. 470–479, 2013.
- [26] S. AlSamak, N. Gkantidis, E. Bitsanis, and P. Christou, "Assessment of potential orthodontic mini-implant insertion sites based on anatomical hard tissue parameters: a systematic review," *The International Journal of Oral & Maxillofacial Implants*, vol. 27, no. 4, pp. 875–887, 2012.
- [27] K. S. Hu, M. K. Kang, T. W. Kim, K. H. Kim, and H. J. Kim, "Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation," *The Angle Orthodontist*, vol. 79, no. 1, pp. 37–45, 2009.
- [28] S. H. Kim, Y. S. Choi, E. H. Hwang, K. R. Chung, Y. A. Kook, and G. Nelson, "Surgical positioning of orthodontic mini-implants with guides fabricated on models replicated with cone-beam computed tomography," *American Journal of orthodontics and dentofacial orthopedics*, vol. 131, no. 4, pp. S82–S89, 2007.
- [29] C. Morea, J. E. Hayek, C. Oleskovicz, G. C. Dominguez, and I. Chilvarquer, "Precise insertion of orthodontic miniscrews with a stereolithographic surgical guide based on cone beam computed tomography data: a pilot study," *International Journal of Oral & Maxillofacial Implants*, vol. 26, no. 4, pp. 860–865, 2011.
- [30] Y. T. Wang, J. H. Yu, L. J. Lo, P. H. Hsu, and C. L. Lin, "Developing customized dental miniscrew surgical template from thermoplastic polymer material using image superimposition, CAD system, and 3D printing," *BioMed Research International*, vol. 2017, Article ID 1906197, 2017.
- [31] K. Miyazawa, M. Kawaguchi, M. Tabuchi, and S. Goto, "Accurate pre-surgical determination for self-drilling miniscrew implant placement using surgical guides and cone-beam computed tomography," *European Journal of Orthodontics*, vol. 32, no. 6, pp. 735–740, 2010.
- [32] X. T. Jia, X. Chen, and X. F. Huang, "Influence of orthodontic mini-implant penetration of the maxillary sinus in the infra-zygomatic crest region," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 153, no. 5, pp. 656–661, 2018.
- [33] M. Motoyoshi, R. Sanuki-Suzuki, Y. Uchida, A. Saiki, and N. Shimizu, "Maxillary sinus perforation by orthodontic anchor screws," *Journal of Oral Science*, vol. 57, no. 2, pp. 95–100, 2015.
- [34] A. Gracco, S. Tracey, and U. Baciliero, "Miniscrew insertion and the maxillary sinus: an endoscopic evaluation," *Journal of Clinical Orthodontics*, vol. 44, no. 7, pp. 439–443, 2010.
- [35] R. Fah and M. Schatzle, "Complications and adverse patient reactions associated with the surgical insertion and removal of palatal implants: a retrospective study," *Clinical Oral Implants Research*, vol. 25, no. 6, pp. 653–658, 2014.
- [36] M. S. Al Amri, H. M. Sabban, D. H. Alsaggaf et al., "Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal," *Annals of Saudi Medicine*, vol. 40, no. 4, pp. 330–337, 2020.
- [37] A. Tavares, K. Montanha-Andrade, P. R. Cury, I. Crusoe-Rebello, and F. S. Neves, "Tomographic assessment of infra-zygomatic crest bone depth for extra-alveolar miniscrew insertion in subjects with different vertical and sagittal skeletal patterns," *Orthodontics & Craniofacial Research*, vol. 25, no. 1, pp. 49–54, 2022.
- [38] M. G. Laursen, B. Melsen, and P. M. Cattaneo, "An evaluation of insertion sites for mini-implants: a micro - CT study of human autopsy material," *The Angle Orthodontist*, vol. 83, no. 2, pp. 222–229, 2013.
- [39] C. Wawrzinek, T. Sommer, and H. Fischer-Brandies, "Microdamage in cortical bone due to the overtightening of orthodontic microscrews," *Journal of Orofacial Orthopedics*, vol. 69, no. 2, pp. 121–134, 2008.
- [40] N. K. Lee and S. H. Baek, "Effects of the diameter and shape of orthodontic mini-implants on microdamage to the cortical bone," *American Journal of orthodontics and dentofacial orthopedics*, vol. 138, no. 1, pp. 8–9, 2010.
- [41] S. S. Y. Liu, E. Cruz-Marroquin, J. Sun, K. T. Stewart, and M. R. Allen, "Orthodontic mini-implant diameter does not affect in-situ linear microcrack generation in the mandible or the maxilla," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 142, no. 6, pp. 768–773, 2012.
- [42] E. Taing-Watson, T. R. Katona, K. T. Stewart et al., "Microdamage generation by tapered and cylindrical miniscrew implants after pilot drilling," *The Angle Orthodontist*, vol. 85, no. 5, pp. 859–867, 2015.
- [43] S. Yadav, M. Upadhyay, S. Liu, E. Roberts, W. P. Neace, and R. Nanda, "Microdamage of the cortical bone during mini-implant insertion with self- drilling and self-tapping techniques: A randomized controlled trial," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 141, no. 5, pp. 538–546, 2012.
- [44] M. V. Nguyen, J. Codrington, L. Fletcher, C. W. Dreyer, and W. J. Sampson, "Influence of cortical bone thickness on miniscrew microcrack formation," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 152, no. 3, pp. 301–311, 2017.
- [45] Z. Gurdan and J. Szalma, "Evaluation of the success and complication rates of self-drilling orthodontic mini-implants," *Nigerian Journal of Clinical Practice*, vol. 21, no. 5, pp. 546–552, 2018.
- [46] T. F. Assad-Loss, F. M. F. Kitahara-Ceia, G. S. Silveira, C. N. Elias, and J. N. Mucha, "Fracture strength of orthodontic mini-implants," *Dental Press Journal of Orthodontics*, vol. 22, no. 3, pp. 47–54, 2017.
- [47] Y. Hirai, K. Watanabe, T. Deguchi, K. Ueda, K. Hamada, and E. Tanaka, "Influence of insertion depth on stress distribution in orthodontic miniscrew and the surrounding bone by finite element analysis," *Dental Materials Journal*, vol. 40, no. 5, pp. 1270–1276, 2021.
- [48] C. A. Vieira, F. Pires, W. T. Hattori, C. A. de Araujo, M. A. Garcia-Junior, and D. Zanetta-Barbosa, "Structural resistance of orthodontic mini-screws inserted for extra-alveolar anchorage," *Acta Odontológica Latinoamericana*, vol. 34, no. 1, pp. 27–34, 2021.
- [49] R. A. Meursinge Reynders, L. Ronchi, L. Ladu, F. van Etten-Jamaludin, and S. Bipat, "Insertion torque and success of orthodontic mini-implants: a systematic review," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 142, no. 5, pp. 596–614.e5, 2012, e5.
- [50] M. Motoyoshi, M. Hirabayashi, M. Uemura, and N. Shimizu, "Recommended placement torque when tightening an orthodontic mini-implant," *Clinical oral implants research*, vol. 17, no. 1, pp. 109–114, 2006.
- [51] N. Ganzer, I. Feldmann, and L. Bondemark, "Pain and discomfort following insertion of miniscrews and premolar

- extractions: a randomized controlled trial," *The Angle Orthodontist*, vol. 86, no. 6, pp. 891–899, 2016.
- [52] C. M. Chen, C. S. Chang, Y. C. Tseng, K. R. Hsu, K. T. Lee, and H. E. Lee, "The perception of pain following interdental microimplant treatment for skeletal anchorage: a retrospective study," *Odontology*, vol. 99, no. 1, pp. 88–91, 2011.
- [53] K. H. Zawawi, "Acceptance of orthodontic miniscrews as temporary anchorage devices," *Patient preference and adherence*, vol. 8, pp. 933–937, 2014.
- [54] R. Reynders, L. Ronchi, and S. Bipat, "Mini-implants in orthodontics: a systematic review of the literature," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 135, no. 5, pp. 564–565, 2009.
- [55] E. Justens and H. De Bruyn, "Clinical outcome of miniscrews used as orthodontic anchorage," *Clinical Implant Dentistry and Related Research*, vol. 10, no. 3, pp. 174–180, 2008.
- [56] S. Sreenivasagan, A. K. Subramanian, and B. Nivethigaa, "Assessment of insertion torque of mini-implant and its correlation with primary stability and pain levels in orthodontic patients," *The Journal of Contemporary Dental Practice*, vol. 22, no. 1, pp. 84–88, 2021.
- [57] S. Kuroda, Y. Sugawara, T. Deguchi, H. M. Kyung, and T. Takano-Yamamoto, "Clinical use of miniscrew implants as orthodontic anchorage: success rates and postoperative discomfort," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 131, no. 1, pp. 9–15, 2007.
- [58] S. N. Papageorgiou, I. P. Zogakis, and M. A. Papadopoulos, "Failure rates and associated risk factors of orthodontic miniscrew implants: A meta-analysis," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 142, no. 5, pp. 577–595.e7, 2012.
- [59] A. C. M. Melo, A. R. Andrighetto, S. D. Hirt, A. L. M. Bongioiolo, S. U. Silva, and M. A. D. da Silva, "Risk factors associated with the failure of miniscrews - a ten-year cross sectional study," *Brazilian Oral Research*, vol. 30, no. 1, article e124, 2016.
- [60] C. H. Moon, D. G. Lee, H. S. Lee, J. S. Im, and S. H. Baek, "Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region," *The Angle Orthodontist*, vol. 78, no. 1, pp. 101–106, 2008.
- [61] M. D. Casana-Ruiz, C. Bellot-Arcis, V. Paredes-Gallardo, V. Garcia-Sanz, J. M. Almerich-Silla, and J. M. Montiel-Company, "Risk factors for orthodontic mini-implants in skeletal anchorage biological stability: a systematic literature review and meta-analysis," *Scientific Reports*, vol. 10, no. 1, p. 5848, 2020.
- [62] Y. Lee, S. H. Choi, H. S. Yu, T. Erenebat, J. Liu, and J. Y. Cha, "Stability and success rate of dual-thread miniscrews," *The Angle Orthodontist*, vol. 91, no. 4, pp. 509–514, 2021.
- [63] Y. H. Kim, S. M. Yang, S. Kim et al., "Midpalatal miniscrews for orthodontic anchorage: factors affecting clinical success," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 137, no. 1, pp. 66–72, 2010.
- [64] Z. Jing, Y. K. Wu, W. L. Jiang et al., "Factors affecting the clinical success rate of miniscrew implants for orthodontic treatment," *International Journal of Oral & Maxillofacial Implants*, vol. 31, no. 4, pp. 835–841, 2016.
- [65] S. B. Hong, B. Kusnoto, E. J. Kim, E. A. BeGole, H. S. Hwang, and H. J. Lim, "Prognostic factors associated with the success rates of posterior orthodontic miniscrew implants: a subgroup meta-analysis," *The Korean Journal of Orthodontics*, vol. 46, no. 2, pp. 111–126, 2016.
- [66] S. A. Lim, J. Y. Cha, and C. J. Hwang, "Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length," *The Angle Orthodontist*, vol. 78, no. 2, pp. 234–240, 2008.
- [67] N. Topouzelis and P. Tsaousoglou, "Clinical factors correlated with the success rate of miniscrews in orthodontic treatment," *International Journal of Oral Science*, vol. 4, no. 1, pp. 38–44, 2012.
- [68] A. G. Crismani, M. H. Bertl, A. G. Celar, H. P. Bantleon, and C. J. Burstone, "Miniscrews in orthodontic treatment: review and analysis of published clinical trials," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 137, no. 1, pp. 108–113, 2010.
- [69] B. Florvaag, P. Kneuert, F. Lazar et al., "Biomechanical properties of orthodontic miniscrews. an in-vitro study. An In-vitro Study," *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*, vol. 71, no. 1, pp. 53–67, 2010.
- [70] M. Marquazan, C. T. Mattos, E. F. Sant'Anna, M. M. G. de Souza, and L. C. Maia, "Does cortical thickness influence the primary stability of miniscrews? A systematic review and meta-analysis," *The Angle Orthodontist*, vol. 84, no. 6, pp. 1093–1103, 2014.
- [71] D. Novsak, M. T. Zrinski, and S. Spalj, "Machine-driven versus manual insertion mode: influence on primary stability of orthodontic mini-implants," *Implant Dentistry*, vol. 24, no. 1, pp. 31–36, 2015.
- [72] M. Motoyoshi, M. Inaba, A. Ono, S. Ueno, and N. Shimizu, "The effect of cortical bone thickness on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone," *International Journal of Oral and Maxillofacial Surgery*, vol. 38, no. 1, pp. 13–18, 2009.
- [73] I. G. A. W. Ardani, R. Indharmawan, and T. Hamid, "Effets de la longueur des mini-vis et de la densité osseuse sur la résistance d'ancrage : une étude in vitro," *International Orthodontics*, vol. 17, no. 3, pp. 446–450, 2019.
- [74] V. Samrit, O. P. Kharbanda, R. Duggal, A. Seith, and V. Malhotra, "Bone density and miniscrew stability in orthodontic patients," *Australian Orthodontic Journal*, vol. 28, no. 2, pp. 204–212, 2012.
- [75] D. W. Lee, J. H. Park, R. C. Bay, S. K. Choi, and J. M. Chae, "Cortical bone thickness and bone density effects on miniscrew success rates: a systematic review and meta-analysis," *Orthodontics & Craniofacial Research*, vol. 24, Suppl 1, pp. 92–102, 2021.
- [76] M. Nienkemper, N. Santel, R. Honscheid, and D. Drescher, "Orthodontic mini-implant stability at different insertion depths sensitivity of three stability measurement methods," *Journal of Orofacial Orthopedics*, vol. 77, no. 4, pp. 296–303, 2016.
- [77] R. Parmar, V. Reddy, S. K. Reddy, and D. Reddy, "Determination of soft tissue thickness at orthodontic miniscrew placement sites using ultrasonography for customizing screw selection," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 150, no. 4, pp. 651–658, 2016.
- [78] A. Manni, M. Cozzani, F. Tamborrino, S. De Rinaldis, and A. Menini, "Factors influencing the stability of miniscrews. A retrospective study on 300 miniscrews," *The European Journal of Orthodontics*, vol. 33, no. 4, pp. 388–395, 2011.

- [79] H. S. Park, S. H. Jeong, and O. W. Kwon, "Factors affecting the clinical success of screw implants used as orthodontic anchorage," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 130, no. 1, pp. 18–25, 2006.
- [80] E. Y. Suzuki and B. Suzuki, "Placement and removal torque values of orthodontic miniscrew implants," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 139, no. 5, pp. 669–678, 2011.
- [81] N. Gupta, S. M. Kotrashetti, and V. Naik, "A comparative clinical study between self tapping and drill free screws as a source of rigid orthodontic anchorage," *Journal of Oral and Maxillofacial Surgery*, vol. 11, no. 1, pp. 29–33, 2012.
- [82] R. M. Reynders and G. Cacciatore, "No confidence that success rates of self-drilling and self-tapping insertion techniques of orthodontic mini-implants are similar," *Evidence-Based Dentistry*, vol. 17, no. 4, pp. 111–113, 2016.
- [83] S. Hoste, M. Verduyts, M. Quirynen, and G. Willems, "Risk factors and indications of orthodontic temporary anchorage devices: a literature review," *Australian Orthodontic Journal*, vol. 24, no. 2, pp. 140–148, 2008.
- [84] B. Wilmes and D. Drescher, "Impact of bone quality, implant type, and implantation site preparation on insertion torques of mini-implants used for orthodontic anchorage," *International Journal of Oral and Maxillofacial Surgery*, vol. 40, no. 7, pp. 697–703, 2011.
- [85] S. Omasa, M. Motoyoshi, Y. Arai, K. Ejima, and N. Shimizu, "Low-level laser therapy enhances the stability of orthodontic mini-implants via bone formation related to BMP-2 expression in a rat model," *Photomedicine and Laser Surgery*, vol. 30, no. 5, pp. 255–261, 2012.
- [86] J. Matys, R. Flieger, G. Tenore, K. Grzech-Lesniak, U. Romeo, and M. Dominiak, "Er:YAG laser, piezosurgery, and surgical drill for bone decortication during orthodontic mini-implant insertion: primary stability analysis-an animal study," *Lasers in Medical Science*, vol. 33, no. 3, pp. 489–495, 2018.
- [87] M. Rismanchian, S. H. Raji, D. Teimori Rik et al., "Effects of immediate orthodontic and orthopedic forces on perimicroscrew bones: histomorphologic and histomorphometric assessment in dogs," *International Journal of Dentistry*, vol. 2012, Article ID 851740, 6 pages, 2012.
- [88] P. V. P. Oltramari-Navarro, R. L. Navarro, J. F. C. Henriques et al., "The impact of healing time before loading on orthodontic mini-implant stability: a histomorphometric study in minipigs," *Archives of Oral Biology*, vol. 58, no. 7, pp. 806–812, 2013.
- [89] K. K. Garg and M. Gupta, "Assessment of stability of orthodontic mini-implants under orthodontic loading: a computed tomography study," *Indian Journal of Dental Research*, vol. 26, no. 3, pp. 237–243, 2015.
- [90] M. Araghbidikashani, A. Golshah, N. Nikkerdar, and M. Rezaei, "In-vitro impact of insertion angle on primary stability of miniscrews," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 150, no. 3, pp. 436–443, 2016.
- [91] H. J. Lim, Y. J. Choi, C. A. Evans, and H. S. Hwang, "Predictors of initial stability of orthodontic miniscrew implants," *The European Journal of Orthodontics*, vol. 33, no. 5, pp. 528–532, 2011.
- [92] E. J. W. Liou, B. C. J. Pai, and J. C. Y. Lin, "Do miniscrews remain stationary under orthodontic forces?," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 126, no. 1, pp. 42–47, 2004.
- [93] M. Nienkemper, J. Handschel, and D. Drescher, "Systematic review of mini-implant displacement under orthodontic loading," *International Journal of Oral Science*, vol. 6, no. 1, pp. 1–6, 2014.
- [94] J. W. Pittman, A. Navalgund, S. H. Byun, H. Huang, A. H. Kim, and D. G. Kim, "Primary migration of a mini-implant under a functional orthodontic loading," *Clinical Oral Investigations*, vol. 18, no. 3, pp. 721–728, 2014.
- [95] Y. C. Wang and E. J. Liou, "Comparison of the loading behavior of self-drilling and predrilled miniscrews throughout orthodontic loading," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 133, no. 1, pp. 38–43, 2008.
- [96] M. Marquezan, A. O. de Freitas, and L. I. Nojima, "Miniscrew covering: an alternative to prevent traumatic lesions," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 141, no. 2, pp. 242–244, 2012.
- [97] S. S. Al-Kharsa and A. I. Masoud, "A proposed method for covering a mini-screw head while maintaining space for ligation," *International Journal of Orthodontics*, vol. 28, no. 1, pp. 65–66, 2017.
- [98] T. Ziebur, S. Flieger, and D. Wiechmann, "Mini-implants in the palatal slope—a retrospective analysis of implant survival and tissue reaction," *Head & Face Medicine*, vol. 8, no. 1, p. 32, 2012.
- [99] A. Acocella, C. Ercoli, A. Geminiani et al., "Clinical evaluation of immediate loading of electroeroded screw-retained titanium fixed prostheses supported by tilted implant: a multicenter retrospective study," *Clinical Implant Dentistry and Related Research*, vol. 14, pp. e98–e108, 2012.
- [100] M. Leo, L. Cerroni, G. Pasquantonio, S. G. Condo, and R. Condo, "Temporary anchorage devices (TADs) in orthodontics: review of the factors that influence the clinical success rate of the mini-implants," *La Clinica Terapeutica*, vol. 167, no. 3, pp. E70–e77, 2016.
- [101] T. Takaki, N. Tamura, M. Yamamoto et al., "Clinical study of temporary anchorage devices for orthodontic treatment—stability of micro/mini-screws and mini-plates: experience with 455 cases," *The Bulletin of Tokyo Dental College*, vol. 51, no. 3, pp. 151–163, 2010.
- [102] R. C. Santiago, F. O. de Paula, M. R. Fraga, N. M. S. P. Assis, and R. W. F. Vitral, "Correlation between miniscrew stability and bone mineral density in orthodontic patients," *American journal of orthodontics and dentofacial orthopedics*, vol. 136, no. 2, pp. 243–250, 2009.
- [103] A. Pauls, M. Nienkemper, and D. Drescher, "Accuracy of torque-limiting devices for mini-implant removal: an in vitro study," *Journal of Orofacial Orthopedics*, vol. 74, no. 3, pp. 205–216, 2013.
- [104] S. Nakagaki, M. Iijima, Y. Yasuda et al., "Effectiveness of methods for detaching orthodontic implants likely to fracture upon rotational torque - an animal study," *Clinical and Experimental Dental Research*, vol. 2, no. 1, pp. 51–56, 2016.
- [105] S. F. Moghaddam, A. Mohammadi, and A. Behroozian, "The effect of sandblasting and acid etching on survival rate of orthodontic miniscrews: a split-mouth randomized controlled trial," *Progress in Orthodontics*, vol. 22, no. 1, p. 2, 2021.
- [106] Y. J. Choi, D. W. Lee, K. H. Kim, and C. J. Chung, "Scar formation and revision after the removal of orthodontic miniscrews," *Korean Journal of Orthodontics*, vol. 45, no. 3, pp. 146–150, 2015.

- [107] S. A. Jung, Y. J. Choi, D. W. Lee, K. H. Kim, and C. J. Chung, "Cross-sectional evaluation of the prevalence and factors associated with soft tissue scarring after the removal of miniscrews," *The Angle Orthodontist*, vol. 85, no. 3, pp. 420–426, 2015.
- [108] C. Teekavanich, M. Uezono, K. Takakuda, T. Ogasawara, P. Techalertpaisarn, and K. Moriyama, "Evaluation of cortical bone microdamage and primary stability of orthodontic miniscrew using a human bone analogue," *Materials*, vol. 14, no. 8, p. 1825, 2021.
- [109] J. G. St Martin, F. Javed, P. E. Rossouw, and D. Michelogiannakis, "Influence of mini-screw implant-assisted intrusion on orthodontically induced inflammatory root resorption: a systematic review," *European Archives of Paediatric Dentistry*, vol. 22, no. 3, pp. 341–349, 2021.
- [110] D. A. Harris, A. S. Jones, and M. A. Darendeliler, "Physical properties of root cementum: part 8. Volumetric analysis of root resorption craters after application of controlled intrusive light and heavy orthodontic forces: a microcomputed tomography scan study," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 130, no. 5, pp. 639–647, 2006.
- [111] R. Abellan, C. Gomez, and J. C. Palma, "Effects of photobiomodulation on the upper first molar intrusion movement using mini-screws anchorage: a randomized controlled trial," *Photobiomodulation, Photomedicine, and Laser Surgery*, vol. 39, no. 8, pp. 518–527, 2021.
- [112] A. Manosudprasit, W. Chantadilok, and M. Manosudprasit, "Management of alveolar bone exostosis after orthodontic treatment," *Journal of Clinical Orthodontics*, vol. 55, no. 4, pp. 401–413, 2021.
- [113] N. Agrawal, A. Kallury, K. Agrawal, and P. P. Nair, "Alveolar bone exostoses subsequent to orthodontic implant placement," *BML Case Reports*, vol. 2013, 2013.