Orthodontic mini-implants: A Systematic review.

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Abstract

Purpose
To compile and analyze the literature regarding orthodontic mini-implants (MIs) placement, clinical applications, success rate, adverse effects and patients' pain experience in clinical practice.
Methodology
Publications about orthodontic MIs variables were systematically searched from PubMed, Science Direct, and Google Scholar Beta electronic data bases using "orthodontic in conjunction with implant, microimplant, screw, miniscrew, screw implant, mini-implant, and temporary anchorage" as keywords. Data from selected articles were extracted and compiled to produce a summarized report.
Results
Several areas are suitable for MI placement. However; the region between second premolar and first molar is the safest. The MI success rate ranges from 77.7% to 93.43%. The pain associated with MIs is far less than tooth extraction and significantly lower than patients' expectation. Root resorption is among the adverse effects and gonial angle pattern influences the MI success rate.
Conclusion
MIs offer a wide range of clinical anchorage application due to their minimal anatomical location limitation. The success rate of MI is reliably high. The pain caused by orthodontics MI is significantly lower than patients' expectation.

Key words: Orthodontics, mini-implant, implant, mini-screw.

Introduction

The use of implants in dentistry began when Branemark (1) published the success of osseointegrated titanium endosseous implants. Implants in dentistry are mostly used for prosthetic reasons,(2) but in the past two decades, they have been incorporated into the orthodontic field for anchorage purposes.(1-5)
The first use of a surgical screw as anchorage was described by Creekmore in a case report of a single patient but this did not immediately attract a lot of attention.(6) Terms such as miniscrew, miniscrew implants, microscrew, and temporary anchorage devices are synonymous to mini-implant (MI).
Mini-implants offer orthodontic clinicians a minimally intrusive method of intra-arch anchorage that can translate entire quadrants with no untoward reciprocal results that afflict interarch techniques.(7) The elimination of interarch mechanics for correcting sagittal discrepancies, the reduction of treatment time, the simplification of treatment mechanics, the correction of midline discrepancies without interarch mechanics, and the ability to move entire quadrants rather than individual teeth are advantages of orthodontic MIs clinical applications.(7-11) Further advantages include small size, minimal anatomic limitations, minor surgery, increased patient comfort, immediate loading, and lower costs.(12-15)

So far, several studies have researched different aspects of orthodontic MI. The following are the topics assessed by various articles in this review: Orthodontic min-implant placement or insertion, clinical applications, success rate or stability, patient's pain perception, adverse effects, and patients' acceptance of MI.

Methods employed to investigate orthodontic min-implants include the use of cone beam computer tomography imaging, finite element models, x-ray superimposition and visual analogue scale (VAS) questionnaire. Since more prospective clinical studies have been published on the area of MIs recently, we therefore compiled and synthesized the literature to elicit insight of orthodontic MIs in clinical practice.

Material and methods

Search strategy: Two reviewers searched the PubMed, ScienceDirect and Google Scholar Beta data bases for articles on orthodontic mini-implants from 1983 to January 2012. A librarian assisted in article searching process. We used ''orthodontic'' as the main heading in combination with the following keywords: implant, microimplant, screw, miniscrew, screw implant, mini-implant, and temporary anchorage with the appropriate character truncation or explore search terms for each search engine. We searched for the MI articles assessing the following topics: Orthodontic MI placement or insertion, success rate or stability, adverse effects, patients' pain perception and acceptance of MIs.

All abstracts retrieved were discussed by the two reviewers for next stage review process. Full articles of accepted abstracts were then retrieved and further assessed for inclusion criteria. The selected studies were subjected to validity assessment by study validity assessment method described by Morgan et al.(16) The articles were independently read by the reviewers to extract two set of data onto structured data forms. The extracted data were further discussed by a panel of three researchers including those who processed the two set of data. Some authors of relevant studies were contacted for additional information.

Selection criteria: Selection criteria included (i) studies that analyzed the patients' pain experience and acceptance; adverse effects, placement protocol and success in relation to mini-implants orthodontic anchorage; (ii) clinical studies without age and sex limitation. Technique articles, case reports, opinion articles, reviews, and laboratory, animal, and in-vitro studies were excluded.

Results

The two reviewers with the assistance of a librarian identified forty-five abstracts; however, they reached consensus to exclude eleven of them after discussion. Thirty-four full articles were retrieved for further assessment of which two were acquired through contacting the authors. When the full articles were discussed, sixteen of them did not meet inclusion criteria, hence only eighteen studies were included in the review. **Table 1** shows the characteristics of studies included in the review. We could not perform meta-analysis of the compiled data due to incomparable study methods. Of the reviewed studies, seven reported about placement aspects (suitable location, insertion techniques and surgical area preparation), three researched on pain perception and patients acceptance of orthodontic MIs, nine articles investigated on various factors associated with MI success rate. However, several case reports and animal experiments with interesting findings for orthodontic practices are discussed in this review. They are not included in literature synthesis.

Based on articles read in review, the region mesial to mandibular first molar is the safest area for MIs insertion. Several other anatomical regions are also recommended. Four insertion guide techniques are suggested for clinical use (**Table 2**). The pain or discomfort due to MI is reported to be far less than pain caused by tooth extraction, and majority of patients are satisfied with MI treatment (**Table 3**). The success rate of MI ranges from 77.7 % to 93.4 %, and several factors influence MI success (**Table 4**).

Discussion

The topics reviewed are MI placement or insertion, success rate or stability, adverse effects, patients' pain perception and acceptance of MIs. There are some inconsistencies in some findings reported by different studies including the recommended location for MI insertion,(17-19) success rate and factors influencing MI success.(20-27) This is mainly due to differences in study design and study participants.

Orthodontic mini-implant placement: There are three considerations in locating proper MI position: the point of implant insertion, the angle of implant insertion in the anterior-posterior direction, and the angulation of implant insertion in the vertical plane.(28) With different study designs, six articles assessing MI placement were retrieved in this review about areas/sites suitable for MI insertion, insertion guide techniques, insertion area preparation techniques and angulations (Table 2).

Anatomical areas suitable for min-implant insertion: Dumitrache et al,(17) Park et al,(18) Kau et al(19) and Baumgaertel(29) examined the safe locations for MI placements. Based on study designs, they cited various areas to be safe for orthodontic MI placement. However, despite their different methods, two studies(17,18) noted the region between second premolar and first molar to be a safe zone for implantation of MIs.

Dumitrache et al(17) mapped the implant sites in the region of the attached gingiva around the maxillary first molars by radiographic examinations and concluded that, the mesial areas of the first molars constitute safe zones for implantation of MI where as the distal areas of the first molars, require an individualized radiographic study before any MI can be placed because of their great variability.

In order to assess the safety and stability aspects of MI placement, Park et al(18) used cone-beam 3-dimensional volumetric images and found that, the safe locations for MI with adequate interradicular space are between the

Table 1: Characteristics of included studies

Included study	Year	Design of study	Sample size	Research validity
Dumitrache et al(17)	2010	Prospective	58 Jaws	Moderate
Park et al(18)	2009	Prospective	60 patients	High
Kau et al(19)	2010	Retrospective	35 MIs	Moderate
Calderón et al(20)	2011	Prospective	13 patients	Moderate
Chen et al(21)	2006	Prospective	29 patients	High
Sharma et al(22)	2011	Retrospective	73 patients	High
Ji et al(23)	2008	Prospective	286 MIs	High
Moon et al(24)	2010	Retrospective	306 patients	High
Türköz et al(25)	2011	Prospective	62 patients	High
Wehrbein et al(26)	2009	Prospective	22 patients	High
Antoszewska et al(27)	2009	Prospective	130 patients	High
Al-Suleiman et al(28)	2011	Prospective	40 MIs	Moderate
Wu et al(30)	2006	Prospective	41 patients	High
Morea et al(31)	2011	Prospective	4 patients	Low
Wu et al(40)	2009	Retrospective	166 patients	High
Baxmann et al(45)	2010	Prospective	28 patients	High
Chen et al(46)	2011	Prospective	40 MIs	High
Lee et al(47)	2008	Prospective	37 patients	High

Table 2: Placement of Min-implants

Recommendation on min-implant location.		
Study	**Study design**	**Conclusion /Recommended area for implant**
Dumitrache et al(17)	Radiographic map of the implant sites in the region of the attached gingiva around the maxillary first molars	Mesial areas of maxillary first molars Caution: Distal areas of the first molars require an individualized radiographic study.
Park et al(18)	Cone-beam 3-dimensional volumetric images of 60 adult patients	Bucal mesial areas of maxillary first molars, distal areas of the first molars, between the molars in the maxillary palatal alveolar bone; interradicular spaces from the first premolar to the second molar in mandibular buccal alveolar bone, midpalatal area and retromolar pad area
Kau et al(19)	Cone-beam evaluation of the location of MI and relate the placement to the surrounding dentoalveolar structures	There is more space for MIs placement in the mandible than in the maxilla.
Recommendation for placement guide technique		
Study	**Recommended guide technique**	
Al-Suleiman et al(28)	Aleppo University Surgical Orthodontic Miniscrew Guide [AUSOM]	
Wu et al(30)	Radiographic and surgical template	
Morea et al(31)	Stereolithographic surgical guide	

Table 3: Perceived Pain and acceptance of min-implants

Study	Study design/aim	Pain experience	MI pain Vs Tooth extraction	Patients acceptance
Baxmann et al(45)	Compared pain associated with MI placement, tooth extraction, and gingival tissue removal in preparation for implant placement.	30% No pain in MI placement produced	MI causes less pain than tooth extraction	Not reported
Chen et al(46)	Using visual analog scale (VAS), investigated differences and changes in the level of pain among patients in relation to orthodontic MI treatments.	35.8 mm VAS1 day after first premolar extraction 12.4 mm VAS 1day after MI placement	One day after procedure: MIs have less pain than tooth extraction	Patients were willing to adopt the MI treatment.
Lee et al(47)	Patients' expectations, acceptance, and experience of pain with MI surgery compared to other orthodontic procedures	Day 1 mean VAS 36.61 Day 7 mean VAS 6.50	No difference during insertion procedure.	Most patients (76%) were satisfied with the MI surgery

Table 4: Factors associated with success rate of min-implants

Study	Over-all success rate	Increase success rate	Reduce success rate	No influence on success rate
Calderón et al(20)	NR	Sandblast and acid-etch Mandible Length 8-mm MI	Maxilla Length 6-mm and 10-mm MI	NR
Chen et al(21)	84.7%	Length 8-mm MI	Length 6-mm MI	NR
Sharma et al(22)	87.8%	Good oral hygiene Low mandible angel	Poor oral hygiene High mandible angle	Sex, Jaw, Site, Side Overbite Skeletal or dental relationship
Ji et al(23)	82.5%	Adulthood	Young age	Sex
Moon et al(24)	79.0%	Average gonial angle	Young age High gonial angle	Sex, Age, Side Soft-tissue management
Türköz et al(25)	77.7%	Drill free	Large drill diameter	NR
Wehrbein et al(26)	91.0%	NR	NR	NR
Antoszewska et al(27)	93.4%	Placement attached gingival En-masse distalization Molar intrusion	Open bite	Sex, Age Mandible angle
Wu et al(40)	89.9%	Diameter ≤ 1.4 mm Left side Good oral hygiene	Right side Poor oral hygiene	Sex, Age MI Length Jaw

NR; Not reported

second premolar and the first molar in the maxillary buccal alveolar bone, between the molars in the maxillary palatal alveolar bone, and interradicular spaces from the first premolar to the second molar in the mandibular buccal alveolar bone. The midpalatal area and the retromolar pad area are also excellent locations for microimplant placement. The cortical bone thickness and bone depth of the palatal alveolar process are, on average, favorable for the insertion of orthodontic MI; other sites should be routinely avoided to prevent damage to the maxillary sinus unless 3-dimensional imaging is available (29). This is one of the non-clinical studies, it is therefore not included in synthesis table. A research by Kau et al(19) found more space for MI placement in the mandible than in the maxilla and that, Clinicians should expect 71.2% of the length of the screw section of the MI to be embedded in the alveolar bone; the percentage is often higher in the maxilla than in the mandible. Although the results in these studies(17-19,29) are not homogeneous, they display the requirement for safe insertion region to be considered when planning for MI placement.

Insertion guide technique: Mini-implants are primarily placed in complex sites where critical anatomic structures, such as roots of teeth are potential to be damaged; so precise surgical planning is required prior to placement.(30) Four articles(28,30-32) reported on the use of different MI insertion guide techniques. They used four different study designs and equipments: Al-Suleiman et al (28); Aleppo University Surgical Orthodontic Miniscrew Guide [AUSOM], Morea et al;(31) stereolithographic surgical guides, Yu et al;(32) surgical stent, Wu et al(30) Radiographic and surgical template. Every study however; emphasized its technique to be appropriate for orthodontic MI insertion.

Aleppo University Surgical Orthodontic Miniscrew Guide [AUSOM] was found to be a practical and accurate placement guide for orthodontic MI device.(28) AUSOM, with four components: a horizontal part, a vertical part, a graduation guide, and film-holding part; works as a radiographic-locating device and a mini-implant surgical placement guide. The failure rate of MI placed by AUSOM was lower than that of those placed by simple metallic guides. Increased precision during the process of MI insertion would help prevent screw loss, potential root damage and improve treatment outcomes. Using cone beam computed tomography (CBCT) data Morea et al(31) evaluated stereolithographic surgical guide suitability and accuracy for one-component orthodontic MI placement. The study stated that, the use of stereolithographic surgical guides allows for accurate orthodontic mini screw insertion without damaging neighboring anatomic structures. Surgical stent was found to be an accurate guide tool for MI placement and recommended for clinical use by Yu et al;(32) this non-clinical study finding cannot be equally compared with studies done on human due to anatomical structure differences. Their findings however have clinical relevance. Wu et al(30) advocated their innovation 'Radiographic and surgical template for placement of orthodontic MI. With this technique, the planned placement site is radiographed using a radiographic template and film holder. The resultant radiograph is clipped and attached to the radiographic template to make a surgical template to guide the placement of the MI. In conclusion the technique was said to improve MI placement accuracy. Of the four studies(28,30-32) every one commends own technique. This is due to the different techniques employed by researchers. In this case, comparative clinical trials are important to find out the precision of various techniques in order for clinicians to have informed choice on MI insertion guide technique in order to maximize the MIs treatment achievement.

The proper angle of MI insertion is important for cortical anchorage, patient safety, and biomechanical control. However, the actual impact of different insertion angulations on stability is unknown.(33) Park et al(8) and Jasmine et al(33) examined the angulations of orthodontic MI. Mini-implant need to be distally inclined about 10 degrees to 20 degrees and placed 0.5 to 2.7 mm distal to the contact point to minimize root contact according to sites and levels, except into palatal interradicular bone between the maxillary first and second molars.(8) Jasmine et al(33) found that placement of MI at a 90° angulation in the bone reduces the stress concentration, thereby increasing the likelihood of implant stabilization and that offers more stability to orthodontic loading. Since the study methods and aim were different, it is logical the two studies(8,33) to recommend different angulation for MIs placement. Whereas Park et al(8) aimed at minimizing potential root contact according to sites and levels for stability, Jasmine et al(33) recommend perpendicular insertion to reduce the stress concentration, thus increasing implant stabilization. Clinicians should have these concepts in mind when deciding the MI angulation.

Apart from safety and stability, treatment goal is another factor for clinician to consider when deciding the location of MI in clinical practice. When force is loaded on a molar region positioned MI to retrude anterior teeth, the pull exerts both vertical and horizontal force vectors at different magnitude depending on the position of MI. The resultant teeth movement includes vertical (intrusion/extrusion) and horizontal (retrusion). This phenomenon has an implication on planning for MI position with regard to various gonial angles pattern; as it can affect the occlusal plane thus may cause un-wanted outcome like anterior open or deep bite.

Success rate

Many factors affect the success of MI. The factors fall under three groups: patient oriented, clinician oriented and MI oriented factors.(20-23,34-38) The overall success rate of MI ranges from 77.7 to 93.43 (Table4). High success rates 93.43% and 91% were reported by studies investigating factors influencing success rate of MI.(26,27) Sandblasting and acid treatment of MIs are reported to offer good bone anchoring for orthodontic purposes.(20) Sand blasted mini-implants surfaces offer good condition for osseointegration, thus improving their stability.(39)

Bone quality and pre-drilling has an impact on the MI primary and long term stability.(34,35) In cases of thick cortical bone Cho et al(34) suggested predrilling for MI to reducing microdamage without compromising orthodontic MI stability. Wilmes et al(35) found the insertion moments of orthodontic MIs, and hence primary stability, varied with compact bone thickness, implant design, and pre-drilling at the implant site. Insertion torques increased with smaller pre-drilling diameters and compact bone thickness, thus optimum pre-drilling diameters should be chosen, to avoid fractures and high bone stresses.

There is a risk of bone damage when forced insertion of self-tapping orthodontic mini-implants on hard bone is employed; narrow drill for site preparation increases orthodontic screw insertion torque, but also decreases removal torque.(36) There are potential risks for MI fracture during placement and micro bone damage when small pre-drill holes are used and implant failure in large hole.(34-36) Clinicians must use the optimal pre drill size to achieve the optimal outcome. Türköz et al (25) compared the stability of mini-implants using drill-free and drilling methods. Significant differences were found between drill and drill-free groups. Mini-implants using the drill-free method provided the highest success rate.

Placement depth and bone density at the site of MI placement are the best predictors of primary stability.(37) Clinician should consider the important trade-off between anchorage and risk of placement complications or damage to the tissues. Longer MIs enable more anchorage; however, they are associated with a higher risk of damage to neighboring structures.(21,37) Careful pre-drilling diameter selection for different locations is recommended to optimize MI success. Mini-implant diameter of 1.4 mm or less for maxilla and larger than 1.4 mm diameter for mandible implants reported to have good results.(40) The extreme lengths of MIs are associated with poor success rate. 8-mm is reported to have higher success rate than 6-mm and 10-mm MI.(20,21)

Patient factors, including vertical position of implant placement, oral hygiene status, and inflammation are associated with orthodontic MI anchorage success rate.(22) The high mandibular angle is reported to have low MI success rate(22,24) This observation may be explained by relatively low bone density among dolicocephalic profiled patients. It has been pointed-out that subjects with brachycephalic faces, with small gonial angles and mandibular plane angles, have thicker cortical bone than average- and long-faced groups.(41-43)

Primary stability is absence of mobility in the bone bed after MI placement and depends on bone quality, among other factors. Cortical bone thickness and density varies according to the region of placement. Areas with thick cortical bone are considered the most stable for MI placement. Since retention depends essentially on the bone-metal interface, the greater the bone, the better the primary stability. Mini-implant primary stability is not affected by trabecular bone area and bone mineral density.(44)

When investigating the clinical failure rate of self-drilling MI anchorages in relation to patient's gender and age, Ji et al(23) found no significant relationship between the stability of MI and gender. However the failure rate of MIs in children was significantly higher than those in adults. The use of MI with washer is one way of improving stability by decreasing the stress on the surrounding bone thus decreasing the MI displacement.(38)

Adverse effects

Pain and discomfort are among the unwanted outcomes of orthodontic MI use (Table 3). When compared tooth extraction and fixed appliance insertion procedures, studies show less pain experience with MI than with any of them, and that patients tend to overestimate the pain anticipated in MI placement.(45-47)

Comparing pain associated with MI placement, tooth extraction, and gingival tissue removal in preparation for implant placement showed extractions discomfort to be significantly greater than during tissue removal and MI placement.(44) Unlike other orthodontic procedures, patients expected to experience a significantly higher level of pain with MI surgery than they experienced. Most patients were satisfied with the MI surgery and majority would recommend it to a friend or family member.(47) And the visual analog scale (VAS) score one day after MI placement is significantly less than that one day after first premolar extraction or that one day after fixed appliance insertion Chen et al.(46) Cifter et al(11) investigated root resorption as one of orthodontic therapy adverse effect and recommended the apical region of the first premolar roots and the apical region of the first molar mesial root to be considered prone to resorption during posterior teeth intrusion treatment.

With clinical experience, MI fracture during insertion is a rare but an embarrassing complication which may need surgical removal of the fractured tip of the MI from the bone. It is worth to avoid it by all possible means.

Wilmes et al(35) and Barros et al(48) investigated the impact of MI diameter on the fracture risk during insertion. Based on their findings fracture moments vary with diameter of the MIs and that, the increase in MI diameter significantly influences the increases of placement torque and reduces the fracture risk. Nevertheless, self-drilling efficacy is not strongly influenced by diameter.

Orthodontic MI is relatively new and fast growing technique in practice. The literature contains a lot of scattered information. Our work and other reviews on this field help to amalgamate and display valuable facts available in scientific data bases.

Conclusion

Based on the findings by the reviewed articles, many locations are suitable for MI placement. The region between second premolar and first molar is the safest. The success rate of MI is reliably high (77.7%- 93.43%). The pain caused by orthodontics MI is significantly lower than patients' expectation.

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