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Effect of Operator-Related Factors on Failure Rate of Orthodontic Mini-Implants (OMIS) used as Temporary Anchorage Devices (TAD); Systematic Review

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Abstract

Aim: This review aimed to determine the operator-related variables that may influence the clinical performance and failure rate of orthodontic mini-implants (OMIs) used as anchorage devices.

Materials and Methods: A search was performed through electronic databases; PubMed, EMBASE searched via ScienceDirect and Cochrane Library. Reference lists were limited to English papers ranging from 2012 to 2018. Eligibility criteria were defined by considering the (PICOS) question patients who received OMIs for orthodontic anchorage. Inclusion and exclusion criteria were performed independently by two authors.

Results: A lot of factors have been proven to affect the success rate of the OMIs, whereas root-proximity and secondary insertion of the mini-implant revealed to be the most significant factors for OMIs failure.

Conclusions and Recommendations: The OMIs should be placed as far as possible from the root, and secondary insertions of failed primary implants should also be avoided.

Keywords: Mini-Implants; Temporary Anchorage Device; OMIs; TAD; Orthodontic Anchorage

Introduction

To achieve the best successful results in orthodontic treatment, anchorage control should be thoroughly managed. The most recent way to gaining this goal is by using mini-implants which have been accepted all over the world [1-5].

Mini-implants are the smallest temporary anchorage devices (TAD) that can be used in different sites of the oral cavity, and in areas that are not reachable by any other types of orthodontic anchorage appliances [6,7]. Such devices are also accepted by most of the patients [8,9].

A lot of research has been conducted to test the success rate of orthodontic mini-implants (OMIs), showing an average success rate of approximately 84% [10,11]. Further research (meta-analysis) reported an overall failure rate of 13.5% for orthodontic mini-implants [12].

The failure rate of orthodontic mini-implants proved to be affected by lots of variables which including: Patient-related factors comprising: oral hygiene measures, smoking, cortical bone thickness, as well as age of the patient [13-16].

Operator-related factors (technical factors) comprising : root proximity, insertion torque, insertion angle, besides amount of orthodontic load [OMIs are stable within forces of 50 g (0.5 N) to 450 g (4.5 N)], direction of load, time of loading (Immediate vs delayed), primary or secondary (re) insertion as well as placement site [12,13,16-22,26-34].

Mini-implant - related factors comprising: screw-diameter, screw length, implant material and insertion method [13,15,35-40]. In general, a success rate of OMIs greater than 80% should encourage the operator to use it. Scanning of the latest systematic literature reviews and meta-analyses, the technical operator-related factors revealed to have the main impact on OMIs success [10,12,41,42].

This review will try to extend and focus on the parameters related to operator related variables, that could influence the failure rate of orthodontic mini-implants (OMIs).

Materials and Methods

Eligibility (Inclusion and Exclusion) Criteria

The selection criteria for this review were defined by considering the PICOS question as following:

1- Population (P): Patients of both sexes, without restriction on age, ethnic, or socioeconomic groups were included. Their orthodontic treatment with fixed appliances required skeletal anchorage.
2- Intervention (I): Intervention comprised the placement of orthodontic MIs for skeletal anchorage.
3- Comparison (C): OMIs insertion angle, amount of orthodontic load,direction of load and placement site were compared.
4- Outcome (O): Mini-implant fracture, patient pain or discomfort and loss of mini-implant stability considered as failure. These outcomes are evaluated twice, primary and secondary: -

- Primary outcome: evaluating all described signs before OMIs functions finishing. Measured immediately after implant insertion.
- Secondary outcome: evaluating all described signs after OMIs functions finishing Measured after the healing phase.

5- Study design (S): (Table 1).

Search strategy for identification of studies

Databases: With filtering of the last 5 years researches, only English papers were selected, because studies of languages other than English (LOE) mainly tend to be of lower quality than studies written in English. Moreover, few of these studies could have the criteria for inclusion into the review, but are still not representative of all the LOE studies [43,44]. Hence, the studies were limited to English language only.

Our search was started at 2018-1-14. The Electronic databases and search strategies are shown in **Appendix 1.**

Included articles:	Excluded articles:
a. Randomized Controlled trails (RCTs). b. Non-randomized clinical studies. c. Prospective and retrospective.	a. Single case reports b. Literature review. c. Systematic reviews or meta-analysis

Table 1: Study design followed in this study

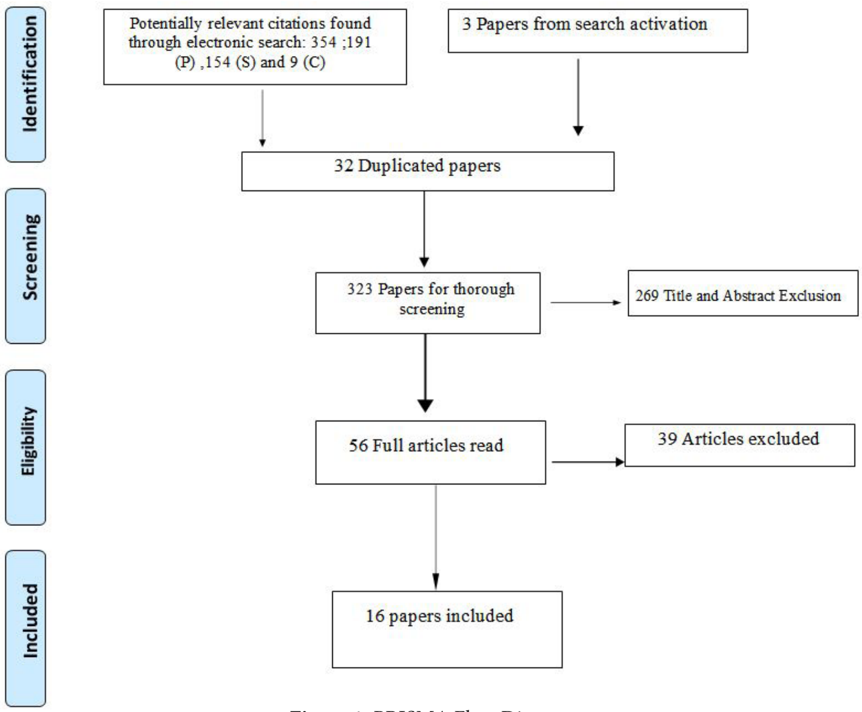

Figure 1: PRISMA Flow Diagram

All papers were collected in Reference manager (EndNote X7), and managed as following:

All titles and summaries of collected publications were reviewed in order to exclude inadequate articles. Full versions of remaining, possibly appropriate articles were reviewed. Full texts of articles', which eligibility could not be evaluated by reviewing their summaries, were read in order to avoid incorrect exclusions. The process of articles' selection is presented in the PRISMA flow diagram (Figure 1).

Data extraction and management

Two authors independently extracted study characteristics and outcomes from the included studies. Miniscrew implant failure counts were extracted as a binary outcome and converted to failure event rates. The primary outcome was the overall miniscrew implant failure rate, and associated factors were the secondary outcomes. Risk factors were assessed by comparing two or more event rates provided by a study.

Assessment of risk of bias of the studies

Two authors assessed independently the risk of bias of the included studies using the Cochrane Collaboration's tool for assessing risk of bias by means of RevMan (version 5.2) as guided by the Cochrane Handbook for Systematic Reviews of Interventions [45]. The following domains were considered: (1) adequate sequence generation, (2) allocation concealment, (3) blinding of participants and personnel, (4) incomplete outcome data, (5) selective outcome reporting, and (6) other sources of bias. For all included studies, the risk of bias for each domain was judged as low risk, high risk, or unclear risk. Each randomized controlled trial was assigned an overall risk of bias in terms of low risk (low for all key domains), high risk (high for ≥1 key domain), and unclear risk (unclear for ≥1 key domain).

Results

357 articles were collected after primary electronic database search. The search results are shown in the PRISMA flow diagram. 32 duplicated items were found, and the remaining 323 articles analyzed their titles and abstracts in detail. The articles which had not confirmed the inclusion requirements were rejected and 56 articles full texts were downloaded and read. After applying the inclusion and exclusion criteria, 16 articles were kept, complete list of included studies shown at Table 2. The excluded 39 papers after full text screening were mentioned in **Appendix 2.**

Discussion

• All included studies were evaluated for the quality based on modified Feldmann and Bondmark suggested method under five criteria: 1) sample size, 2) research method, 3) research object description, 4) research technique and 5) study design. After qualitatively evaluating all articles, they were divided into two categories: of high (8-10 points) (3-9,11, 34-36) and medium (6-7 points) (10, 12) quality (Table 3) [46].
• 4418 OMIs of 12 different manufacturers (Chopra *et al.* 2015) and 4 different types of materials (Titanium, titanium alloy, Titanium-vanadium alloy and stainless steel) which had been threaded in 1709 patients' upper and lower jaws at different areas, were analyzed.
• The samples of analyzed OMIs were not less than 28 OMIs (Albogha *et al.* 2016) and not exceeding 1375 OMIs (Melo et al. 2016). The number of 10-570 patients were included in the search. The analyzed OMIs were used for anchorage of the dentition for at least 3.5 months. The success rate of MI was assessed in the analyzed articles.
• Diameter of OMIs ranged from 1.2-2.3 mm and their length ranged from 6-12 mm (Table 2).
• The technical operator-related factors affecting the success rate of OMIs included; selected placement site (including root proximity), insertion torque, insertion angle, amount of orthodontic load, direction of load, time of loading (Immediate vs delayed) and primary or secondary (re) insertion. The included studies focused on: insertion site (including root proximity), insertion angle (most of included studies focused on vertical angle), amount, direction, as well as onset of loading.
• Uesugi *et al.* 2017 described the effect of secondary insertion of OMIs on the success rate of OMIs, being about 44.2% for all re-inserted types.
• OMIs were inserted in different areas, but most of the studies placed them between the 2nd premolar and 1st molar (especially in the Maxilla). These inserts were used for different purposes but most of authors used it for retraction of the anterior segment.
• The applied load used in all included studies, and it ranged from 50-300 gm, while a few papers did not even describe the amount of load applied (Table 2).
• The OMI stability/success/failure affecting factors were analyzed in all articles, however, authors had given different definitions of a "successful" MI (Table 2). A successful MI is that implant which performs its' function as a skeletal anchorage device for a certain period of time (6-12 months), or during the entire orthodontic treatment period without any notable mobility, surrounding soft tissue inflammation or any other pathologies.
• Root proximity has been found to be the most significant factor for OMIs failure, and therefore at least 1mm clearance should exist between root and OMIs. Janson *et al.* 2013 declared that: OMIs root proximity didn't influence the success rate as long as there was no periodontal ligament invasion. Albogha *et al.* 2016 stated that if OMIs is slightly apically inclined, reducing the vertical angulation, the OMI will be away from the roots. He also declared that with a small interradicular width, the OMI

should be placed closer to the root opposing the force direction that will be applied later. Garg *et al.* 2015 supported the evidence of Albogha *et al.* 2016 by proving that the OMIs do not remain absolutely stationary like the end-osseous implant throughout orthodontic loading. Therefore, it is mandatory that in case of small interradicular, the OMI should be placed closer to the root opposite to the future force direction.

• Almost all studies found that the onset of OMIs loading, either immediate or delayed, affects the success rate of OMIs insignificantly, or even having no effect at all. In 2015, Jeong *et al.* recommended the delay of load application, as he found that the immediate loading increased the risk of failure.

• OMIs vertical angulation was measured by different ways in different articles, but not all articles measured the angulation of the mini-implant (Table 2). Some authors measured the angulation of mini-implants to root and others measured it from mini-implant surface to alveolar bone and finally, others measured it to the occlusal plane. The mini-implant angulation ranged from 40-90° with an exception of Jing *et al.* 2016, who started his measurement from 10°-90°. In 2013, Jung *et al.*, and Park *et al.* 2018 declared that cortical bone thickness increased with decreased vertical placement angle, and the success rate increased as the cortical bone thickness increased. Although this association was not statistically significant. All authors consider the OMIs angulation change not a statistically significant.

• The success rate of OMIs used during orthodontic treatment in all included studies ranged from 79.2% to 97%, though the success rate was not presented in some articles.

• The authors in several included studies described many operator-related factors affecting success rate of OMIs. However, the statistically significant factors that affect OMIs success rate were: root proximity as well as secondary insertion of pre-failed OMI.

Author, year and location	**Patients (n) Male/ Female(n) Age (years)**	**OMIs No. and material**	**Diameter and length**	**Insertion area**	**Load (N) (Amount, Direction, Onset**	**Success(S) / failure(f)**	**Mean period of application**	**Implant angulation**	**Failure type**
Albogha *et al.* (2016) South Korea [47]	16 0m/16f 13.5-35.5y	28 DualTopTM titanium Dual-TopTM titanium mini-implants (Jeil Medical Corporation, Seoul, Korea)	(6 mmlength, 1.4 mm diameter	Maxilla buccal alveolar bone between 5 and 6	2 N spring mesial load. Unknown onset	22s/6f	Unknown	Mean = 79.9o	
Chopra *et al.* (2015) India [30]	15 6m/9f mean=15y	30 titanium unknown companies	1.3mm diameter and 8mm length	Maxilla buccal alveolar bone between 5 and 6	150 g elastic chain. Immediate loading	24s/6f	14 mth	Unknown	Mobility or discomfort
Garg *et al.* (2015) India [48]	10 3m/7f 15-23y	40 (Dentos Inc., South Korea)	1.3 mm diameter and 7 mm length	Maxilla and Mandibular buccal alveolar bone between 5 and 7	150 g maxilla 100 g mandible coil spring. Immediate loading	40s/0f	Unknown	Unknown	
Giuliano Maino *et al.* (2012) Italy [49]	144 (51 m/ 93 f 24.6 y (SD, ± 14.1 years)	324 titanium alloy (Spider Screw HDC, Sarcedo, Vicenza, Italy	1.5-2mm diameter, 7-11mm length	Maxilla (tuberosity, edentulous zones and interdental septa)	Immediate with 150g then 300g after 3 months. Immediate loading	296/28 91.4/8.6 %	13.7 mth	90°	

Author, year and location	Patients	OMIs No. and material	Diameter and length	Insertion area	Load (N)	Success(S) / failure(f)	Mean period of application	Implant angulation	Failure type
Hourfar *et al.* (2017) Germany [50]	239 (102 m/137 f) 11.0–16.9 y	387 (OrthoEasy®, Forestadent, Pforzheim, Germany) titanium-vanadium alloy (Ti-6Al-4 V)	(1.7 mm diameter , 8 mm length)	190 in the anterior palate and 197 in buccal inter-radicular sites.	greater than 2Ni Ti Coil spring. immediate loading for the buccal OMIs Palatal OMIs were loaded within 3 days after placement	328s/59f 84.8% 57bucc and 2pal.	Unknown	Unknown	OMIs remaining in situ over the entire period of treatment that required anchorage were recorded as successful. Premature loss or if removal of the OMI become failure necessary before achieving the defined treatment aims were charted unsuccessful.
Janson *et al.* (2013) Brazil [51]	21 9m/12f mean age: 16.99y	40 miniscrews with the same dimensions (Absoanchor, self-drilling thread,Dentos, Daegu, Korea)	,1.5 mm outer diameter, 1.9 mm head diameter, 7 mm length	Maxillary buccal alveolar bone between premolar and molar 5 and 6	100-250 g . immediate loading	36s/4f 90% s	10 mth	Unknown	Loss of stability
Jeong *et al.* (2015) South Korea [29]	134 patients (mean age, 20.08±7.52 years)	331 (Miangan; Biomaterials Korea, Seoul, Korea)	Self-drilling 1.2mm / 7.0mm	Buccal alveolar bone between 4&7 of the maxilla and mandible.		274s / 57f (29 FGB-28 FGA) 82.78 %			
Jing *et al.* (2016) Sichuan China [52]	114 42m/72f 12-18Y	253 (Vector-TASTM, Orm-co)	d: 1.4,2.0 L: 6,8,10	83 in Mandible 170 Maxilla	Different	88.54% 224s/29f (18 mandible, 11 Maxilla)	9.5 M	different se the full text	remained in the bone without loosening until it had accomplished its purpose.
Jung *et al.* (2013) South Korea [53]	130 (33m/97f) 19.24Y +/- 6.66y	228 AbsoAnchor SH1312-08 [self-drilling style, tapered type], Dentos, Taegu, Korea	1.2-1.3 mm in diameter, tapered type, 8 mm in length	Maxillary buccal alveolar bone 110 RS/118LS	50-200 g Elastic chain. immediate loading	200s/28f 87.7% S	Unknown	Vertical: (S:73.75+/-15.29o) (F:75.93+/-13.48o) Horizontal: (S:97.11+/-12.34o) (F:96.65+/-10.06)	Maintained in bone with it's function for over 1 year under orthodontic force during treatment were considered successful

Author, year and location	Patients	OMIs No. and material	Diameter and length	Insertion area	Load (N)	Success(S) / failure(f)	Mean period of application	Implant angulation	Failure type
Melo *et al.* (2016) Brazil [54]	570 147m / 423f	1356 (Neodent, Curitiba, Brazil) conical ;	5, 7, 9 or 11 mm length; and 1.3, 1.4 or 1.6 mm diameter	Max-illa & mandible Buccal & lingual	Different immediate loading	Different	Unknown	Unknown	Implant fracture or mobility
Park *et al.* 2018 South Korea [55]	80 29m / 51f 18±6.1 Y	160 s , AbsoAn-chor SH1312-08 [self- drilling and tapered] titanium alloy; , untreated; Dentos, Daegu, Korea)	1.2–1.3 mmdiam-eter; 8 mm length,	Maxillary buccal alveolar bone between premo-lar and molaar 5 and 6	50 to 200 g . immedi-ate loading using elas-tic chains	M: 47 of 58 81% F:89 of 102 87.2% (85% all)	1 year	s:0-49 f:1.7-50.7	Loss of reten-tion in the alveolar bone for at least 1 year during treat-ment
shinohara *et al.* 2013 Japan [56]	50 patients (15 m/35 f Age range, 13-34 years)	147 (68 in max and 79 in man.) predrilling ISA orthodontic mini-implants; Biodent,Tokyo, Japan)	(Bone drills with diameters of 1.0mm in the maxilla and 1.3 mm in the man-dible)(di-ameter, 1.6 mm;length, 8 mm	Buccal alveolar bone be-tween the second premo-lar and the first molar maxilla or man-dible	2 N . im-mediate loading	95.6% in the maxilla and 93.7% in mandi-ble con-tact root:29 and failed 6 not contact:118 f 2	6 months	Vertical inclinations of 48.3 to 50.4 in the maxillaand 57.5 to 63.3 in the mandible horizontal inclination-sranged from 83æ to 89	Mobility
Tsai *et al.* 2016 Taiwan [57]	139 (25 m /114 f ; average age, 25.7 ± 7.5y age range, 12-56 years)	254 103 Titanium alloy MIs, Ancer, Huang-Liang Bio-medical Technol-ogy, Kaohsiung, Tai-wan; 151 stainless steel MIs, Bio-Ray, Syntec Scientific Corp., Taipei, Taiwan)	Stainless steel 2 × 12 mm, 2 × 10 mm, and 2 × 8 mm; Ti-alloy 2 × 11mm, 2 × 9 mm, and 1.5 × 9 mm)	Different areas	Differ-ent load amount and direc-tion	Different	1 year	Unknown	MI that required removal due to loosening, pain, infection, or pathologic changes in sur-rounding soft tissues
Uesugi *et al.* 2017 Japan [32]	240 (61m/179 f ages, 28.1±9.8 y)	500 titanium miniscrews (Dualtop; Jeil Medical, Seoul, Korea)	Diam-eters (1.4 or 1.6mm) and lengths (6.0 or 8.0 mm)	Different areas see table	Different, ranging from im-mediate loading to 3 months	for 77 screws. The secondary success rate was 44.2% for all reinserted miniscrews (34 of 77 screws)	1-year	Unknown	(1) no inflam-mation of the soft tissues sur-rounding the miniscrews, (2) no clini-cally detectable mobility, and (3) anchorage function sus-tained after 1 year of orthodontic loading

Author, year and location	Patients	OMIs No. and material	Diameter and length	Insertion area	Load (N)	Success(S) / failure(f)	Mean period of application	Implant angulation	Failure type
Uribe *et al.* 2015 USA [58]	30 (mean age 22.2 ± 11 years)	55 with without drilling , Four different types [Lomas (Mondeal, Tuttligen, Germany), Imtec (Unitek 3M, Monrovia, California), Aarhus (Medicon, Tuttligen, Germany), Dual Top (RMO, Denver, Colorado)	D: 1.50 to 2.3 L:6-9mm	Infra-zygomatic area IZA by palpating the "key ridge" above the first permanent molar	Around 150 g Unknown	21.8 % failure rate. This failure rate is slightly higher than that reported for mini-implants placed inter-radicularly.	Average of 13.67 ± 6.79 months	40° to 70° to maxillary occlusal plane	Mini-implant that had to be removed or had fallen out after placement
Yi Lin *et al.* 2015 Singpora [59]	136	285 AbsoAnchor AND Vector TAS	L: 6-7/8/10–12mm D: 1.3/1.4/2.0mm	Different areas	Unknown	94.7% at T1 (immediate after surgery) and 83.3% at T2(12 months after surgery)	3.5 months	Unknown	Dislodgement of the miniscrew implant prior to loading or a miniscrew that has become excessively mobile before 12mth And if the miniscrew implant has caused irreversible biological damage to adjacent structures as recorded by the clinician and was thus unusable, it was also considered a failure.

Abbreviations: N= Newton, mth = Months, f= …..

Table 2: Included studies and comparison factors

Analyzed criteria	Description	Evaluation
Sample size	The quantity of analyzed MI	0-10 – 0 points; 11-20 – 1 point; ≥21 – 2 points
Research Method	Research method used for MI insertion site analysis	None – 0 points; Radiological 2D – 1 point; Radiological 3D, histological analysis or scanning electron microscopy – 2 points
Research object description	The quantity of researched individuals	0-5 – 0 points; 6-10 – 1 point; ≥11 – 2 points
Research technique	Clinical examination, the use of objective measuring device (Periotest, torque screwdriver, orthodontic tension gauge)	Clinical examination – 1 point; The use of objective measuring device – 2 points
Study Design	Controlled, uncontrolled study	Uncontrolled study – 1 point; controlled study – 2 points

Table 3: The quality assessment of the included studies

Conclusion

• Many operator-related factors can affect the success rate of orthodontic mini-implants OMIS, and it should be taken into consideration before placement of the implant.
• The operator should give extra welling to the root proximity and should prevent any secondary insertion of pre-failed OMIs.

Recommendations

• Place the OMIs as far away as possible from the root, and if the space between roots are thin, make the OMI away from the root of force application.
• Avoid secondary insertions of pre-failed OMI.

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