Evaluation of risk factors leading to failure of orthodontic mini-implants in the maxilla: A radiographic study

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Abstract

Introduction: Absolute/skeletal anchorage is used frequently in current clinical orthodontic practice. Using orthodontic miniscrews/mini-implants/bone-screws as temporary anchorage devices, cases requiring critical anchorage can easily be treated without taxing the anchorage unit/units. Success of the orthodontic treatment involving absolute anchorage depends on the survival and stability of the miniscrew. Knowledge of factors that can increase the risk of miniscrew failure are vital to the clinician.

Aim: This study aimed to evaluate the factors responsible for inter-radicular mini-implant failure in the maxilla.

Study design: This retrospective-radiographic study was conducted using archived case record books and CBCT records of patients who received orthodontic miniscrews/mini-implants in the maxillary bone during treatment from January 2022 to January 2023. A total of 30 patients were included in this study. The sample was divided into two groups (15 participants each). Group A-successful miniscrews and Group B-failed miniscrews. The stability was assessed by checking mobility of the mini-implant clinically right after placement (T0), at the time of loading/orthodontic force application (T1) and at the time of removal (T3). The differences in cortical bone thickness and root proximity between the two groups were calculated using unpaired Student's t-test.

Results: Each failed implant was associated with previously recorded hygiene status, quantitative (root proximity, bicortical/mono-cortical anchorage, cortical bone thickness) and qualitative radiological imaging (bone density etc). Statistically significant difference was seen between the two groups regarding bone density, cortical bone thickness, proximity to adjacent roots and oral hygiene ($p<0.05$). Age,

gender, the type of force applied on the mini-implant and mono/bi-cortical anchorage did not affect the implant stability significantly.
Conclusions: The most common factor that led to failure of mini-implant was reduced cortical bone thickness, followed by lesser bone density, close proximity with adjacent roots and root contact. Poor oral hygiene was found to be the most prevalent host factor for mini-implant failure.

Keywords: Absolute anchorage, temporary anchorage devices (TADs), cortical bone thickness (CBT), root proximity, miniscrews, mini-implants, stability

Introduction

Anchorage consideration is a vital part of orthodontic treatment planning. Orthodontists have spent decades dedicated to developing and perfecting an absolute anchorage system that doesn't rely on teeth or group of teeth for anchorage. Such an anchorage system takes support from the underlying skeleton rather than the dental components of the jaws. Although traditional orthodontic mechanics can produce satisfactory results without skeletal/absolute anchorage, unintended anchor loss leads to compromised results & aesthetics, ultimately prolonging the finishing phase and the overall orthodontic treatment. In moderate to critical anchorage cases, where the movement of anchor unit is unfavorable, absolute/skeletal anchorage can be a powerful tool for successful treatment, improved aesthetics, shorter treatment time and better prognosis [1-5].

TADs are most beneficial in cases of bimaxillary protrusion, anterior open bites, deep bite cases, cases requiring occlusal cant correction, cases requiring asymmetric tooth movements etc. Skeletal anchorage is also used for molar uprighting, molar distalization, posterior segment protraction, in mutilated dentitions and in cases where anchor segments are periodontically compromised where traditional anchorage mechanics are bound to fail etc. [2].

These anchorage aids are only useful as long as they are stable under orthodontic forces. Orthodontic implants are designed to retain within the jaw bones mechanically rather than by osseointegration. Osseointegration is not required for TADs as they need to be removed after their purpose is served.[6-13]

Since the beginning of orthodontic implant use, multiple cases of implant failure/mobility have been reported in the literature. Several studies have reported at least a 10% failure rate of implants [15] Several factors have been reported as risk factors for mini-implant failure like poor oral hygiene, excessive force during insertion, inadequate cortical bone thickness (CBT) etc. [14-17]

Authors have reported great initial stability of orthodontic miniscrews and bone screws, and a decline in the success rate over time with force application. Viwattanatipa *et al.* [6] reported a decline in the success rate of mini-implants from 85% at 6 months to 57% after 1 year. However, Cheng *et al.* [15], Miyawaki *et al.* [16] reported different results for decline in the success rate over a 3-year period and a 1-year period respectively. Previous studies have reported varying failure rates at 28% [18], 18.2% [19], 16% [20], 22% [21, 22,] 8% [15] etc. Alharbi *et al.* [23] reported a combined failure rate of 13.5% in a systematic review of 41 studies involving orthodontic mini-implants/miniscrews. These varying results need to be re-checked and the consequent failures thoroughly analysed.

Papageorgiou, Zogakis and Papadopoulos in their systematic review reported no significant correlation of implant failure with sex, age and side of insertion. Peri-implantitis as a result of food in the area surrounding the implant head along with poor oral hygiene is the most prevalent reason for implant failure. [24,25-29] In certain

patients orthodontic mini-implants were seen to repeatedly fail without any signs of tissue inflammation. Thus, the predictability of failure rate is still questionable.
This study aims to analyse and report various factors responsible for failure of orthodontic mini-implants and to determine the factors that can help to predict implant stability before-hand.

Material and Methods

This radiological study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, K. M. Shah Dental College and Hospital, Sumandeep Vidyapeeth, Piparia, Vadodara, Gujarat, after receiving approval from the institute's Ethics Committee approval no. SVIEC/ON/Dent/BNPG22/May/23/49). Treatment records including the case record book and CBCT records of patients undergoing orthodontic treatment (involving TADs) from January 2022 to January 2023 were included in this study.
Inclusion criteria for this study were; case record books of orthodontically treated patients using mini-implants (mentioning the insertion and removal date of the mini-implant), case record books stating the purpose of mini-implant (retraction, distalization & expansion), case record books stating the date of clinically observed mobility (GROUP B), individuals aged 18-30 years (non-growing individuals), CBCT records and interradicular miniscrews placed in the maxilla (buccally, anteriorly or palatally). Exclusion criteria for this study included incomplete/poor treatment records and syndromic patients.
The minimum sample size calculated for this study (95% confidence interval, 90% power) was 12 participants [30]. After application of the set inclusion and exclusion criteria, the sample was filtered and a total of 30 cases were included in this study (15 per group). The mini-implants that served their complete purpose of achieving desired orthodontic tooth movement before removal were categorized as successful mini-implants (GROUP A-successful miniscrews) The mini-implants that failed to serve their purpose and became mobile before achieving the desired orthodontic tooth movement, ultimately leading to removal were categorized as failed mini-implants (GROUP B-failed miniscrews).
The time points taken in this study during data collection to determine failure/success were; T0-date of miniscrew placement, T1-date of miniscrew loading and T2-date of miniscrew removal (after treatment for GROUP A/mid-treatment for GROUP B). Each failed implant was associated with one or more factors of failure based on previously recorded hygiene status and quantitative & qualitative radiological imaging.
The parameters included in this study are described in Table 1.

Table 1: Description of parameters for assessment of risk factors

Sr. No.	Parameter	Abbreviation and Units*	Description
1.	Site of placement	AM, PM, PL	▪ **AM:** Anterior maxilla; interradicular implants placed in the labial cortical plate anteriorly in the canine-canine region ▪ **PM:** Posterior maxilla; interradicular implants placed in the buccal cortical plate posteriorly in the first premolar-to-second molar region ▪ **PL:** Palatal bone; interradicular implants placed anywhere in the palate (medially, paramedially or lateral)

2.	Length of screw used	In millimeters (mm)	Minimum length used 1.3 x 8mm. Maximum length used 1.5 x 9mm.
3.	Bicortical/ monocortical anchorage	BCA, MCA	▪ **BCA:** (Bicortical anchorage) anchorage taken by penetrating both the cortical plates. ▪ **MCA:** (Monocortical anchorage) anchorage taken by penetrating single cortical plate.
4.	Oral hygiene status [34]	Good, Good-to-moderate, Moderate-to-poor, Poor	▪ **Good (Score 0):** No plaque in gingival area. ▪ **Good-to-moderate (Score 1):** A film of plaque adhering to the free gingival margin and adjacent area of tooth; recognizable only by running a probe across the tooth surface. ▪ **Moderate-to-poor (Score 2):** Accumulation of soft deposits within the gingival pocket, on the gingival margin and/or adjacent tooth surface; can be seen with naked eyes. ▪ **Poor (Score 3):** Abundance of soft matter within the gingival margin and adjacent tooth surface.
5.	Cortical bone thickness (in millimeters) [30]	CBT (mm)	The thickness of the buccal/labial/palatal/ cortical plate
6.	Bone density (Misch classification, 1993) [35]	D1, D2, D3, D4	▪ **D1:** Homogenous compact bone throughout the jaw (1250-1900 HU). ▪ **D2:** A thick layer of compact bone surrounding a dense trabecular bone (850-1200 HU). ▪ **D3:** A thin layer of cortical bone surrounds a core a dense trabecular bone (350-850 HU). ▪ **D4:** A thin layer of cortical bone surrounding a core of low-density trabecular bone (150-850 HU).
7.	Purpose of miniscrew	RTR, EXP, DST, PRT, INT, EXT	▪ **RTR:** En masse/2-step retraction. ▪ **EXP:** Dental/skeletal expansion. ▪ **DST:** Molar/en masse distalization. ▪ **PRT:** Molar protraction. ▪ **INT:** Segmental Intrusion. ▪ **EXT:** Extrusion.
8.	Root proximity [33]	RP	▪ Linear distance between the miniscrew and the closest adjacent root.

The linear measurement for CBT was done in the area immediately adjacent to the placed mini-implant. For measuring root proximity, the linear distance from the mini-implant to the root surface closest to it was measured in the axial sections. In case of bicortical anchorage, the thickness of only buccal/labial cortical plate was taken. Although used for different purposes, all the buccal and labial miniscrews were used to engage elastomeric chains. The palatal miniscrews included in this study were used for expansion and molar distalization. In patients who received bilateral miniscrews, the mini-screws were considered as failed (Group B) even if one of the screws failed and the desired tooth movement was not completed.

STATISTICAL ANALYSIS

The included CBCT records were subjected to detailed qualitative and quantitative radiological analyses and the findings were recorded. Other clinical parameters were obtained from the case record books of selected participants. Mean and standard deviation were calculated for the pre-treatment demographic information (age, sex) to determine homogeneity of the included sample. Intergroup comparison was done using the unpaired t-test. The significance level was set at $p<0.05$.

Results

The mean age and percentage of gender distribution is given in Table 2.

Table 2: Comparison of pre-treatment demographic details for successful and failed mini-implant groups

Groups	Group A (n=15) (successful mini-implants)	Group B (n=15) (failed mini-implants)
Mean age	20.9 ± 1.7	21.8 ± 2.7
Gender distribution	M = 33%	M = 20%
	F = 67%	F = 80%

Mini-implant related factors (length, mono-bicortical anchorage), sites of screw insertion, purpose of the mini-implant and oral hygiene statuses were evaluated and compared between the groups (Table 3). 74% of the implants were placed in the posterior maxillary buccal segment, out of which 65% were used for en-masse/2-step retraction of the anterior segment. 13% implants were placed in the anterior maxilla and the palate. In the total sample, 50% participants had received screws of length 1.3 x 8mm and remaining 50% received screws of length 1.5 x 9mm. 90% of the total screws penetrated only one cortex (mono-cortical anchorage) while only 10% screws penetrated both the cortices (bi-cortical anchorage).

Table 3: Comparison (%) of non-quantitative factors related to mini-screws

Parameter		Group A (n=15) (successful mini-implants)	Group B (n=15) (failed mini-implants)	Total Sample (n=30)
1.	Site of placement	PM = 60% AM = 20% PL = 20%	PM = 86% AM = 7% PL = 7%	PM = 74% AM = 13% PL = 13%
2.	Length of mini-screw used	1.3 x 8mm = 60% 1.5 x 9mm = 40%	1.3 x 8mm = 40% 1.5 x 9mm = 60%	1.3 x 8mm = 50% 1.5 x 9mm = 50%
3.	Bi/mono-cortical anchorage	MCA = 87% BCA = 13%	MCA = 94% BCA = 6%	MCA = 90% BCA = 10%
4.	Purpose of miniscrew	RTR = 54% EXP = 6% DST = 14% PRT = 14% INT = 6% EXT = 6%	RTR = 75% EXP = 6% DST = 6% PRT = 0% INT = 13% EXT = 0%	RTR = 65% EXP = 6% DST = 10% PRT = 6% INT = 10% EXT = 3%
5.	Oral Hygiene status	0 = 15% 1 = 60% 2 = 13% 3 = 12%	0 = 6% 1 = 20% 2 = 54% 3 = 20%	0 = 10% 1 = 40% 2 = 34% 3 = 16%

Intergroup comparison between groups A and B regarding cortical bone thickness (CBT) showed a general decreased thickness of the buccal cortical plate in group B (Table 4). Highly significant difference was found in the thickness of the penetrated cortex (CBT) between the two groups. Group A and Group B showed a mean CBT of 1.42mm and 1.04mm respectively (Table 4).

Table 4: CBT comparison between Group A and Group B with p values

Parameters	Group A (successful mini-implants) [Mean ± S.D.]	Group B (Failed mini-implants) [Mean ± S.D.]	Group A vs Group B (p value)
CBT	1.42 ± 0.19	1.02 ± 0.3	0.0001**
Root proximity	0.79 ± 0.09	0.54 ± 0.28	0.006*
Statistically significant* (p<0.05); highly statistically significant** (p<0.001)			

Maximum failed mini-implants (Group B) showed extremely close root proximity (in some cases root contact) (Table 5). 33% of implants failed due to poor oral hygiene statuses.

Table 5: Group B specific data with respect to reason of failure of miniscrew (%) (n=15)

1. Poor oral hygiene (scores 2 & 3)	33%
2. Poor bone density (D3 and D4)	25%
3. Root proximity/contact (≤0.5mm)	42%

Group B participants showed a generally poor oral hygiene (Score 2 = 54%, Table 3; Table 5). Group A participants (successful mini-implants) had a better hygiene status (Score 1 = 60%; Table 3; Table 5).

Discussion

Many orthodontic practitioners use skeletal/absolute anchorage for treating critical anchorage cases [1-4]. Moderate anchorage cases are also routinely treated using this temporary anchorage devices (TADs) in non-compliant patients or in patients who routinely debond/deband the anchor teeth. The prognosis and outcome of such cases depends largely upon the stability of the miniscrew/mini-implant within the oral cavity [6, 14].

Previous studies show a minimal 10% failure rate of orthodontic miniscrews [15-17, 21-24]. Various authors have reported differences in miniscrew stability with respect to the jaw of insertion, quality of bone, anterior/posterior maxilla/mandible etc. [24] vStudies have also shown the mechanical factors that affect failure rates during implant insertion (excessive force and torque values). Health of the soft tissues and oral hygiene status have also been correlated to the survival rate of miniscrews [16]. Factors like age and gender do not influence the success of miniscrews unless a systemic host factor or a deleterious habit such as smoking is present. [36]

However, the failure rates reported in the previous literature are variable and a better knowledge of predictability factors is essential for the clinician for successful treatment. [2,24] Unlike other studies that have analysed the success and failure of mini-screws inserted using different methods (self-drilling and self-tapping), [22] this study only self-drilling interradicular implants were included that were placed in the maxilla.

In the present study, successful and failed mini-implants were evaluated using clinical and CBCT records. Previous studies have mentioned the use of stents and guides for insertion of mini-implants. Previous studies have also recommended the use of radiological imaging prior to miniscrew insertion for better success rates.[33] 3-D imaging has been preferred over 2-D imaging. [30]

In the present study the CBCT records were taken after miniscrew insertion instead of before insertion. The possible factors for failure were determined using clinical records. The results of this study show that most mini-implants failed due to close root proximity or root contact [Figure 1A, 1B, 1C], followed by poor oral hygiene (Table 5). Root contact, when not iatrogenic, might be due to decreased spaces between adjacent roots as the anatomy differs from case to case. [Figure 1D]. However, the most prevalent host factor was oral hygiene (Table 3).

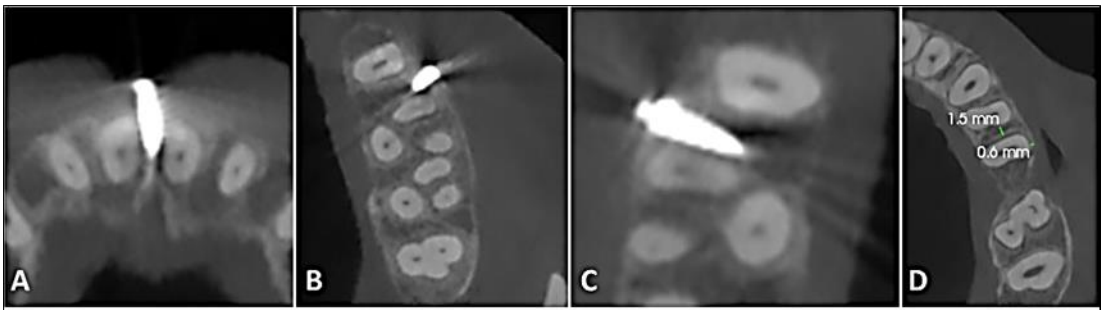

Figure 1: CBCT axial sections showing root contact and proximity; A - larger diameter of screw when used in anterior maxilla increases the risk of root contact; B - Root proximity < 0.5mm; C – Root contact (mesiobuccal root of first permanent molar) in posterior maxilla between second premolar and first molar; D – CBCT section showing inadequate distance between roots of premolars for mini-implant insertion

Congruent with the previous studies, bone density and cortical bone thickness were seen to affect the stability of the miniscrew (Table 4). [30-33] All the miniscrews that served their complete purpose had adequate cortical bone thickness around them (Group A,1.42 ± 0.19); in group B, the cortical bone thickness was reduced (1.02 ± 0.3) [Figure 2]. Recommended CBT for an orthodontic miniscrew is at least 1mm.[30]

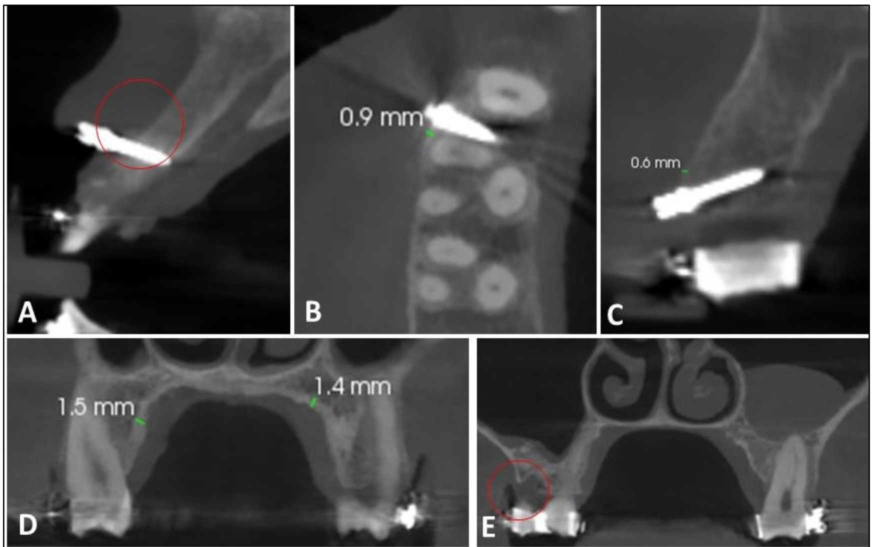

Figure 2: CBCT sections showing CBT; A – miniscrew (1.3 x 8mm) placed in the anterior maxilla showing absence of buccal cortical plate (circled red); B – reduced CBT in posterior maxilla (axial section); C – reduced CBT in posterior maxilla (coronal section, right side, between second premolar and first molar); D – adequate cortical bone thickness in the palatal area (paramedially and laterally); E – Absence of buccal cortical plate in posterior maxilla (circled red)

A few studies have also reported different rates of failure under different types of orthodontic load. The different kinds of mechanics/purposes that the mini-implants were used for in this study are given in Table 3. Because of a smaller sample size, it was difficult to determine the correlation in this study.

Bone density was also evaluated in this study based on Misch classification. [35] Results of this study showed greatest success in areas of dense bone with a thick cortex (D2).

In Group B, 25% (Table 5) of the miniscrews failed due to placement in areas of poor bone density (D3 & D4) [Figure 3]. Previous studies have reported similar findings. [31, 32]

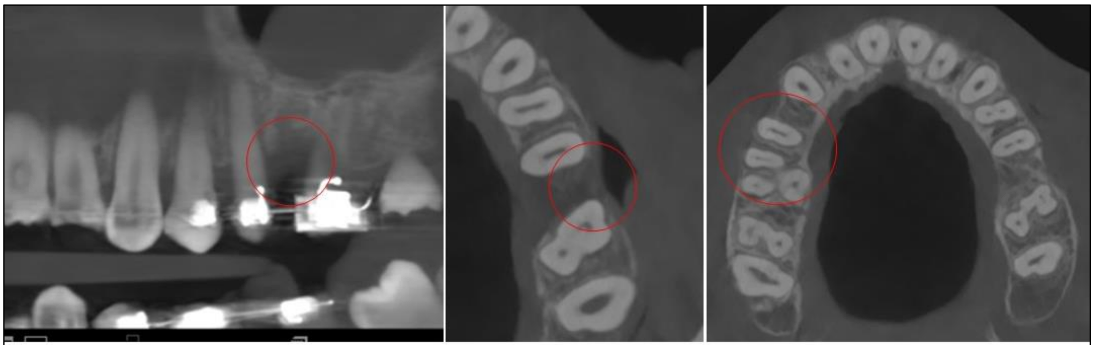

Figure 3: Areas of low bone density seen in the CBCT sections of Group B

Therefore, the success of orthodontic mini-implants depends on two major host factors i.e. bone density/CBT and good oral hygiene. Inflammation around the implant head due to food lodgement and accumulation of plaque is the major cause of implant failure and can be easily controlled with meticulous hygiene practices. CBT, bone density and adequate space for mini-implant placement between adjacent roots can be determined by performing 3D imaging prior to insertion. In case of inadequate space between adjacent roots (Figure 1D), a smaller implant can be selected or the implant can be placed at a different site.

In case of failure, the author recommends reinserting/re-angulating the miniscrew or reusing the failed miniscrews according to the previously reported guidelines. [25-29]

Conclusions

1. Most common host factors leading to failure of orthodontic mini-implants in the maxilla are reduced bone density (D3 and D4), inadequate cortical bone thickness (CBT) and poor oral hygiene.
2. Root proximity should be checked prior to insertion of the miniscrew with CBCT imaging.
3. Iatrogenic root contact/proximity can be avoided by using imaging techniques and selecting mini-implants of adequate dimensions.
4. Pre-insertion CBCT images can also help in determining the bone characteristics of the area of focus/insertion and changing the site of insertion if required. Most ideal bone density was found to be D1 and D2.
5. Smaller dimension implants are more successful in the anterior maxilla.
6. Age and gender do not significantly affect the failure rate of orthodontic mini-implants.

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