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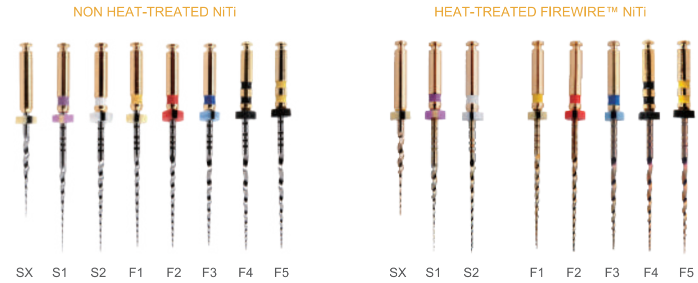

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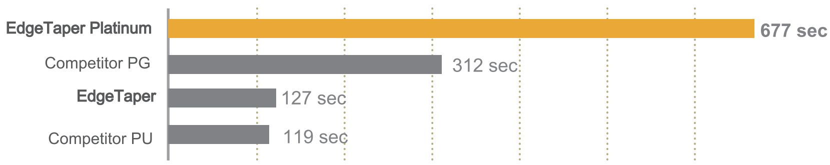

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Assorted pack
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SX19mm,S1,S2,F1,F2,& F3: 21MM	ET21MM
SX19mm,S1,S2,F1,F2,& F3: 25MM	ET25MM
SX19mm,S1,S2,F1,F2,& F3: 31MM	ET31MM

Non-heat treated NiTi / 6pk

	ETSX19

Non-heat treated NiTi / 6pk

PURPLE	ETS121
WHITE	ETS221
YELLOW	ETF121
RED	ETF221
BLUE	ETF321
BLACK	ETF421
YELLOW	ETF521

25mm Non-heat treated NiTi / 6pk

S1	PURPLE	ETS125
S2	WHITE	ETS225
F1	YELLOW	ETF125
F2	RED	ETF225
F3	BLUE	ETF325
F4	BLACK	ETF425
F5	YELLOW	ETF525

31mm Non-heat treated NiTi / 6pk

S1	PURPLE	ETS131
S2	WHITE	ETS231
F1	YELLOW	ETF131
F2	RED	ETF231
F3	BLUE	ETF331
F4	BLACK	ETF431
F5	YELLOW	ETF531

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Assorted pack
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SX19mm,S1,S2,F1,F2,& F3: 21MM	ETP21MM
SX19mm,S1,S2,F1,F2,& F3: 25MM	ETP25MM
SX19mm,S1,S2,F1,F2,& F3: 31MM	ETP31MM

19 mm Heat-Treated FireWire™ NiTi / 6pk

SX	ETSX19HT

21 mm Heat-Treated FireWire™ NiTi / 6pk

S1	PURPLE	ETS121HT
S2	WHITE	ETS221HT
F1	YELLOW	ETF121HT
F2	RED	ETF221HT
F3	BLUE	ETF321HT
F4	BLACK	ETF421HT
F5	YELLOW	ETF521HT

25 mm Heat-Treated FireWire™ NiTi / 6pk

S1	PURPLE	ETS125HT
S2	WHITE	ETS225HT
F1	YELLOW	ETF125HT
F2	RED	ETF225HT
F3	BLUE	ETF325HT
F4	BLACK	ETF425HT
F5	YELLOW	ETF525HT

31mm Heat-Treated FireWire™ NiTi / 6pk

S1	PURPLE	ETS131HT
S2	WHITE	ETS231HT
F1	YELLOW	ETF131HT
F2	RED	ETF231HT
F3	BLUE	ETF331HT
F4	BLACK	ETF431HT
F5	YELLOW	ETF531HT

Insertion Torque and Success of Extra-Alveolar Mandibular Buccal Shelf Miniscrews for Self-Ligation Mechanics

Abstract

Objectives: *1. To assess the correlation between insertion torque and the success rate of miniscrews inserted in mandibular buccal shelf (MBS) region, and 2. to evaluate the impact of the cortical bone thickness, length of endosseous engagement, insertion angle and surface angle on the insertion torque of MBS miniscrews.*

Material and Methods: *128 stainless steel (SS) 2x12-mm MBS miniscrews were placed bilaterally in 64 consecutive patients (24 males and 40 females; mean age 19.5±5 years) and loaded with 10-14 oz (283-397 g) immediately. Insertion torque values were compared between failure and success groups at an interval of six months. Cortical bone thickness, length of endosseous engagement, insertion angle, and surface angle were measured blindly through cone beam computed tomography (CBCT) images.*

Results: *The overall success rate was 89.1%. The insertion torque value was lower in the failure (16.1±7.0 Ncm), compared to the success group (20.1±6.3 Ncm). The success rate was directly related to torque values; however, the t test failed to show any statistical significance. Cortical bone thickness and insertion angle revealed significant positive correlations with insertion torque, but only on the left side. Length of endosseous engagement and surface angle had no significant effect on the insertion torque value.*

Conclusions: *MBS is a region with relatively dense bone quality, where a relatively high insertion torque of the miniscrew is guaranteed compared to inter-radicular miniscrews. Therefore, primary stability of MBS miniscrews is adequate for ensuring success as orthodontic anchorage units. (J Digital Orthod 2023;71:26-39)*

Key words:

Miniscrews, insertion torque, primary stability, success rate, extra-alveolar orthodontic anchorage, mandibular buccal shelf (MBS)

Introduction

By providing absolute anchorage with a predictable survival rate, orthodontic miniscrews have been constantly altering the strategies to treat challenging malocclusions over the past two decades.[1-4] In terms of insertion site, inter-radicular (I-R) placement is more common but risks and difficulties such as root damage,[5-7] displacement under loading,[8-10] and interferences with path of tooth movement are often encountered.[11,12] These problems are especially prominent in the posterior mandible, which leads to increasing failure rates reported by multiple reviews.[13-15] Therefore, miniscrews inserted in the mandibular buccal shelf (MBS) have been proven to be a reliable source of extra-alveolar (E-A) anchorage for retracting the entire mandibular arch to correct severe crowding, protrusion, and skeletal malocclusion without orthognathic surgery (Figs. 1 and 2).[16-18]

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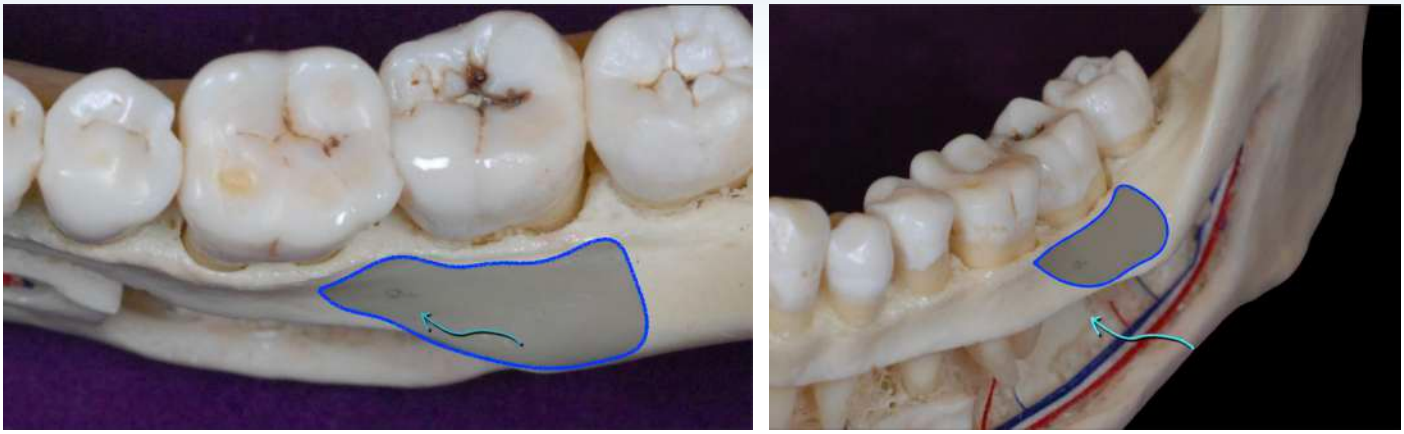
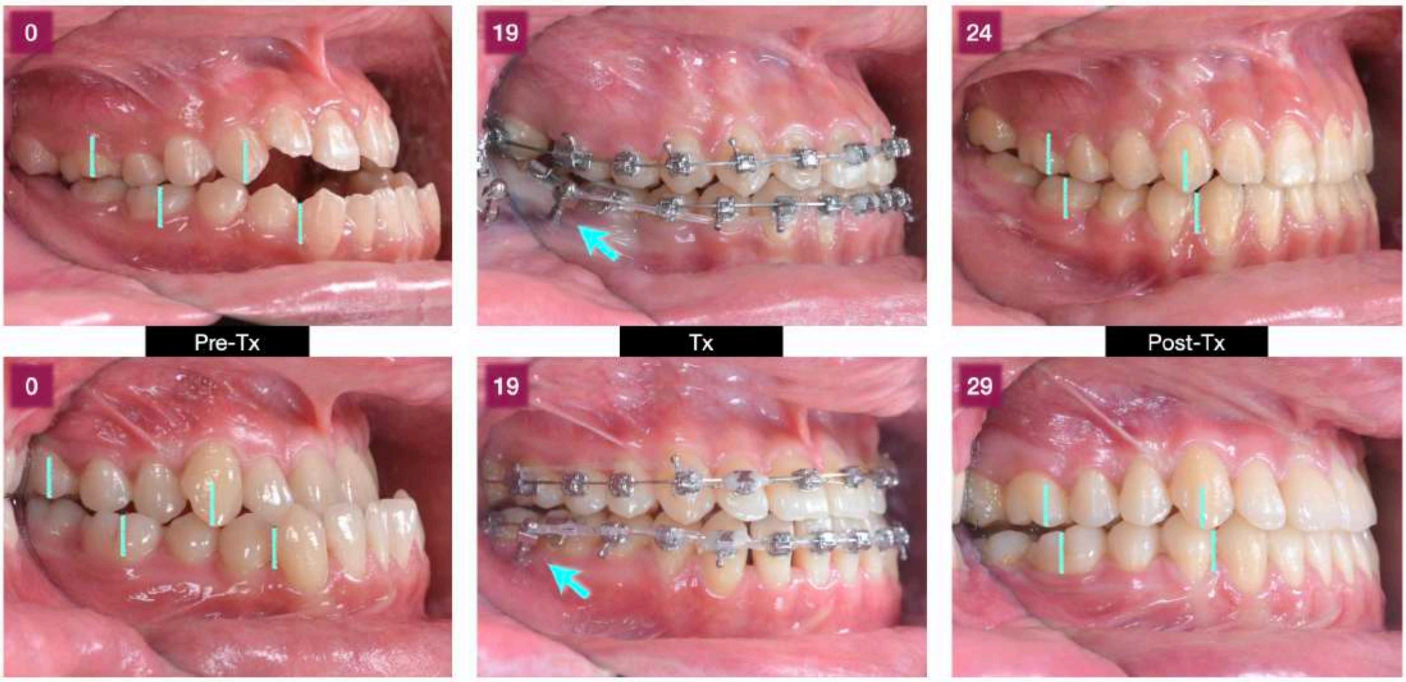
Resident, Beethoven Orthodontic Center (Left)
Chris H. Chang,
Founder, Beethoven Orthodontic Center
Publisher, Journal of Digital Orthodontics (Center)
W. Eugene Roberts,
Editor-in-Chief, Journal of Digital Orthodontics (Right)



■ ***Fig. 1:***
An occlusal view (left) and a lateral view (right) of a human mandible show the available area for mandibular buccal shelf miniscrew insertion.



■ ***Fig. 2:***
A panel of six right buccal intraoral photographs show the pre-treatment (Pre-tx), treatment (Tx), and post treatment (Post-Tx) records for two full-cusp Class III malocclusions (upper and lower panels) treated with MBS miniscrews for elastic chain anchorage (blue arrows). The months of treatment are marked in the upper left corner of each picture. The major mechanics provide both retraction and an intrusive moment on the posterior mandibular segment which are favorable in treating open bite cases.

Due to the demand of immediate loading, primary stability is of utmost importance.[14,19] Screw failure typically occurs in the first few weeks after placement, so the mechanical interlock of a miniscrew with bone is the critical factor for clinical success.[20] Attempts to improve the primary stability include smaller diameter pilot drills or self-drilling methods,[21-24] selection of sites with thicker cortical bone and denser trabecular bone,[25,26] and modified screw designs.[27-29] Among these reports,[21-29] insertion torque is the most frequently used non-invasive quantitative assessment of screw stability. The amount of insertion torque, which is the force to insert a miniscrew, mainly results from the frictional resistance between bone-screw contact.[30,31] 5 to 10 Ncm is generally the recommended range of torque values for I-R miniscrews.[9,31,32] Torque level beyond this range might indicate the existence of root contact and compromise the success.[33] However, the correlation between primary failure rate and insertion torque for E-A miniscrews remains unclear. Moreover, the factors influencing the magnitude of insertion torque in the MBS region have not been thoroughly explored.[11]

It is therefore necessary to understand at what levels torque strains remain physiologic and can guarantee the stability of these E-A miniscrews. The purposes of this study were to compare the primary stability of successful and dislodged groups of MBS miniscrews by using insertion torque measurements, and to explore the validity of a subjective assessment of primary stability through cone beam computed tomography (CBCT) images after miniscrew placement. It was hypothesized that the insertion torque under a certain level would lead to higher MBS miniscrew failure.[34] In addition, cortical bone thickness might be the most important overall factor to determine the insertion torque of MBS miniscrews.[26]

Material and Methods

This study was approved by the Indiana University institutional review board and ethics committee (approval No. 1408974880) in Indianapolis, United States. It is a follow-up of hard tissue research in comparison to the soft tissue research conducted by Chang et al. in 2015.[11] MBS miniscrews were installed in a consecutive series of 64 patients (24 males and 40 females; mean age 19.5±5 years), who were treated with Damon Q® passive self-ligating (PSL) brackets (Ormco Corporation, Brea, CA), and all agreed to take CBCT (KaVo 3D eXam plus, Germany) after the procedure in addition to cooperating with this study. A total of 128 OrthoBoneScrews® (iNewton, Inc., Hsinchu City, Taiwan) (Fig. 3) were placed bilaterally in the MBS area in a private practice by the same senior orthodontist from 2015 to 2018.

A cylinder-shaped 2x12-mm stainless steel (SS) miniscrew was placed as parallel as possible to the mandibular molar axis without raising a flap. The optimal position for MBS miniscrews is lateral to the lower first and second molar contact area, approximately 5-7 mm below the alveolar crest. After local anesthesia, a sharp dental explorer was used to sound to the bone in the preferred location, usually near the mucogingival junction. This dent helps to prevent slippage of the self-drilling miniscrew inserted with a screw driver. At least 5

Fig. 3:
Design specifications for a 2x12-mm stainless steel miniscrew allow for a self-drilling procedure in the mandibular buccal shelf area.

mm of the screw head was left above the level of the soft tissue to facilitate oral hygiene. A strain-gauged manual torque wrench (iNewton, Inc., Hsinchu City, Taiwan) was used to measure the primary stability during the final tightening of the miniscrew. All miniscrews were immediately loaded using pre-stretched power chains (Ormco, Glendora, CA) to deliver a relatively uniform retraction force of approximately 10-14 oz (283-397 g), which were reactivated every 4 weeks.

These MBS miniscrews were checked at every monthly appointment for 6 months. The 6-month assessment interval was selected because primary stability decreases mostly during the first 6 month period after placement. Secondary stability would not overlap with primary stability, because the material of the miniscrew used in the study does not undergo osseointergration. Success is defined as the capability of sustaining the function of orthodontic anchorage, with the absence of inflammation and clinically detectable mobility; whereas the definition of failure is spontaneous loss, severe clinical mobility of the miniscrew requiring replacement, or infected, painful, pathological changes in the surrounding soft tissues. Finally, two of the co-authors were assigned to blindly and individually measure the statistics using CBCT slice view images to evaluate the placement protocol. Measurements including: 1. cortical bone thickness, 2. length of endosseous engagement, 3. insertion angle relative to the lower first molar axis, and 4. acute surface angle relative to the mandibular buccal shelf contour (Fig. 4). The t test were used to assess the measurements data. To explore the possible correlations between parameters, the Pearson correlation analysis were performed. Probability ($p<0.05$) was the minimum level of significance for all tests. The statistical analyses were

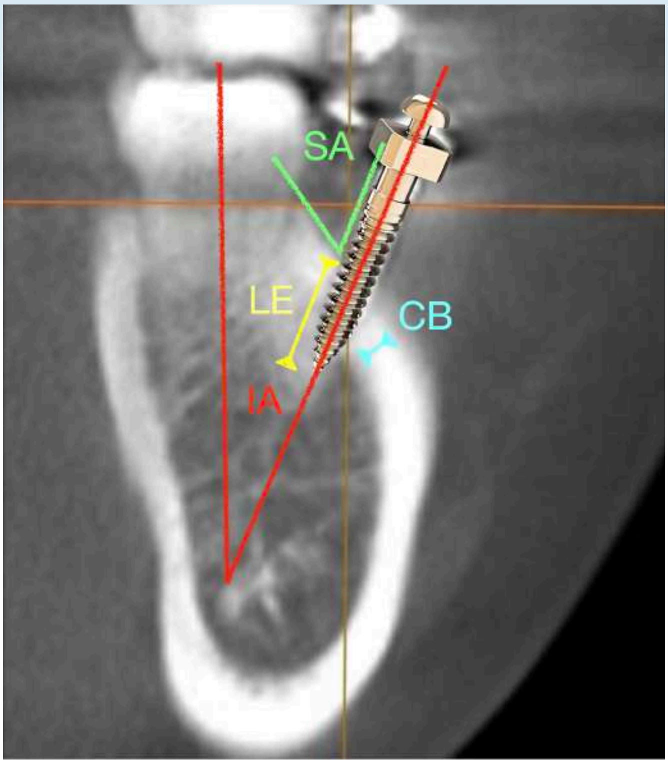


Fig. 4:
A CBCT slice view reveals the position of a MBS miniscrew. The cortical bone thickness (CB) and length of endosseous engagement (LE) were measured. The insertion angle (IA) is delineated between the MBS miniscrew and the mandibular first molar axis, while the surface angle (SA) is shown relating to the buccal shelf bone contour in an acute angle.

carried out with the SPSS statistical package (version 24.0, IBM).

Results

Retrospective analysis of the 128 MBS miniscrews revealed that 14 miniscrews (10.9%) failed within 6 months. Bending or fractures of the miniscrews was not observed in either group during placement. The mean insertion torque value of the failure group were 16.1±7.0 Ncm, while it was 20.1±6.3 Ncm for the success group. Although the success rates seemed to elevate with increasing torque values (Table 1), the t test failed to show any statistical significance on both sides between the groups ($p>.05$), so the hypothesis was rejected (Fig. 5).

On the other hand, Tables 2 and 3 show a positive association between insertion torque and cortical bone thickness (1.8±0.8 mm), but was only significant on the left side ($p<0.05$). The average length of endosseous engagement was 4.7±1.5 mm, and the insertion torque difference was insignificant ($p>.05$). However, there were interesting findings among other variables: the insertion angle showed a highly statistical significance to insertion torque on the left side ($p<0.01$), but not on the right side ($p>0.05$); the surface angle measurements were basically symmetrical in each patient, even though there was a wide range of buccal shelf slopes. It can be inferred from this data that a right-handed practitioner inevitably tends to place miniscrews in different angles bilaterally. The 14 failed miniscrews were collected from a total of only 8 patients. The bilateral failure suggests there may be other factors, such as genetic predispositioin, age or oral hygiene, which have a greater impact on the MBS miniscrew failure than primary stability.

Discussion

The present study is the preliminary research seeking to define the importance of insertion torque to the success of MBS miniscrews, although its relevance to placement specifications should not be overlooked. A major finding was a lack of

Table 1. Success Rates According to Different Insertion Torque Values

Insertion torque (Ncm)	Success	Failure	n	Success rate (%)	*p*
=< 7	4	2	6	66.7%	0.193
8 t0 14	14	3	17	82.4%	
15 to 21	44	5	49	89.8%	
>= 22	52	4	56	92.8%	
Total	114	14	128	89.1%	

Table 1: *Success rates of miniscrews according to different insertion torque values*

Table 2. Means and Standard Deviations of Bone Morphologic Features

	Right		Left	
	Mean	SD	Mean	SD
Cortical bone thickness (mm)	1.82	0.81	1.80	0.86
Length of engagement (mm)	4.56	1.41	4.94	1.57
Insertion angle (°)	36.89	9.74	33.32	10.36
Surface angle (°)	60.78	12.16	57.68	16.11

Table 2: *Means and standard deviations of bone morphologic features*

Table 3. Correlations between Bone Morphologic Features and Insertion Torque Value

	Pearson correlation coefficient	
	Right	Left
Cortical bone thickness (mm)	0.165	0.268*
Length of engagement (mm)	-0.041	-0.061
Insertion angle (°)	-0.044	0.336**
Surface angle (°)	-0.044	0.194

* $p < .05$ ** $p < .01$

Table 2: *Correlations between bone morphologic features and insertion torque value*

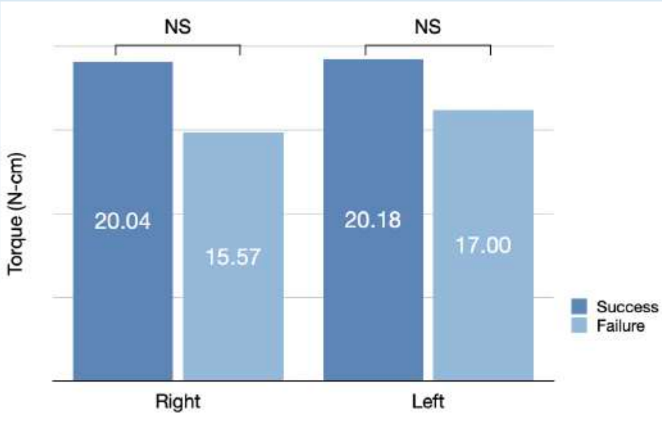


Fig. 5:
There was a tendency for higher mean insertion torque in the success groups on both sides, but the differences were not statistically significant.

significant difference between the insertion torques of the successful and the dislodged groups on either side (Fig. 5). The result indicates that, within the restraints of this study, less primary stability does not appear to be a decisive factor for MBS miniscrew failure. It can be reasoned that the posterior mandibular bone quality, quantity, and geometry result in the MBS being a favorable site selection to provide sufficient stability for the miniscrews. However, oral hygiene control remains an important contributing factor towards MBS miniscrew success, since soft tissue inflammation was the most common reason for the removal of MBS miniscrews.

These findings are not in contradiction to those of other empirical studies, although there are certain important differences regarding other aspects. It is generally recommended to control the insertion torque within the range of 5-10 Ncm for I-R miniscrews.[31,32] As reported by McManus et al.,[9] the mean resistance to movement for miniscrews with a placement torque >5 Ncm was significantly greater than for screws with a placement torque <5 Ncm. A related issue concerns higher insertion torque value indicated for miniscrews with root contact than for those without.[33] The adverse effects refer to orthodontic tooth movement and the survival of miniscrews could be expected if the screw-to-root contact had existed. E-A concept is best achieved by firmly seating screws for intraoral anchorage in basilar bone.[35]

The E-A concept can be mainly divided into two applications: infra-zygomatic crest and buccal shelf placement. A recent study shows that the critical insertion torque for miniscrews inserted in the infra-zygomatic crest (posterior maxilla region) is around 8 Ncm.[36] Previous research has indicated that functional demands on the mandible could result in its developing thicker cortical bone and higher bone density when compared to the maxilla.[9] Therefore, it would be intuitive to expect a greater mean insertion torque for miniscrews placed in the posterior mandible region. In the samples used in this study, due to the fact that a MBS miniscrew with an insertion torque below 8 Ncm is relatively rare (<5%), the finding lends some credence to the explanation of why the critical torque range for MBS miniscrew success cannot be defined. It might be speculated that almost all MBS miniscrews could be placed within the safe torque zone because their predominant position is where the compact alveolar bone exists.

A surprising finding was that the cortical bone thickness was not coherently significantly correlated with the miniscrew insertion torque value. The authors suggest that, unlike many inert materials, bone is not homogeneous, and cortical bone thickness does not reflect bone density or quality.[9] Even though the success rates seemed to be obviously related to the cortical bone thickness in previous observational studies, such as Motoyoshi[37] and Liu et al.,[38-40] it is now hypothesized that cortical bone thicker than 1.0 mm does not necessarily improve the insertion torque value and success rate. The same explanation could also be applied to the absence of significant correlation between the length of endosseous engagement and insertion torque.[39] With regard to the surface angle, our findings echo those of Wilmes[41] and show that the higher torque values were measured when the miniscrews were inserted slightly obliquely at an angle between 60° to 70°. As presented, the insertion angle on the left side was the parameter which showed a highly statistically significant difference in the insertion torque, which might also lead to the marginal statistical significance of the cortical bone thickness on the same side, since different angles would result in different bone thickness engaged.[42] Thus, the better performance on the right side seems to be indicative of the fact that the practice of insertion angle control on the left side could be rectified with a slight increase.

The present study contributes to the field's understanding of the reliability of MBS miniscrew for its good primary stability and high success rate (89.1%). Most people's common impression is that miniscrews inserted into the posterior mandible tend to suffer more failures (16.5-33.3%) than those inserted in the maxilla (6.6-17.2%);[43-46] however, the findings in the present data provide empirical evidence to clarify the "myth". By changing the location from the I-R space to the buccal shelf, one of the major risk factors contributing to the failure of miniscrews - root contact - is ruled out.[47] Moreover, assuming there is adequate soft tissue clearance (approximately 5 mm), miniscrews can be positioned in the attached gingiva or movable mucosa with equal success.[11] Higher insertion torque can be constantly achieved without undue concern about the patient's cortical thickness or the practitioner's clinical skills in the MBS region. Therefore, if oral hygiene and soft tissue inflammation are well managed, practitioners can expect minimal MBS miniscrew failure.[48,49]

Despite demonstrating advantages of MBS miniscrews, the present study does have some limitations. First, not everyone is comfortable using miniscrews as intraoral anchorages.[50-52] This "knowledge to action" gap severely limits MBS miniscrew usefulness in clinical research.[53,54] Particularly challenging is the lack of awareness to differentiate between I-R and E-A TSADs.[17] Furthermore, when learning to use MBS miniscrews, both insertion technique and clinical effectiveness requires a serious time investment.[55] The problem is compounded by the fact that relatively few specialists can actually apply MBS miniscrews well, making it more difficult for novices to find someone to ask for constructive advice.

This kind of instruction is still very much in the early adoption stage and deserves future investigations. Much more is needed about the various ways clinicians use MBS miniscrews, which could further strengthen the case for placing miniscrews in the MBS. The previous publication by Chang et al.[11] in 2015 and this retrospective study provide qualitative soft as well as hard tissue basis for subsequent research. It is hoped that future studies will yield additional data to improve our understanding of the clinical capacity of MBS miniscrews with different orthodontic appliances, e.g., clear aligners.

Conclusions

- High insertion torque can be achieved for most of the miniscrews placed in the mandibular buccal shelf region. There is no significant torque difference between the success and failure groups. Therefore, the adequate primary stability allows immediate loading of up to 300 g with a good rate of clinical success.

- There is no significant correlation between insertion torque and cortical bone thickness or the length of endosseous engagement.

- To achieve a higher insertion torque, a surface angle ranging from 60° to 70° is advisable; while the insertion angle relative to the lower molar's axis is suggested to be controlled at around 35°, especially on the left side for a right-handed practitioner.

- The risk of root contact is eliminated by extra-alveolar placement. If primary stability is well controlled, the clinical challenge is to minimize miniscrew failure by proper oral hygiene management.

Clinical Applications

- Class III camouflage treatment (Fig. 2): Class III with anterior cross-bite, and/or severe open bite may require extensive orthognatic surgery. Patients and parents concerned about expense and complications may request an alternate approach. Conventional alternatives including extractions and/or extensive inter-maxillary elastics may still undergo challenging processes and result in compromised outcomes. On the other hand, MBS miniscrews are effective for managing severe skeletal and Class III malocclusions. Rather than extracting teeth, E-A anchorage corrects crowding by retraction of buccal segments to increase arch length. At the same time, it minimizes the use of inter-maxillary elastics and decreases the iatrogenic incisor tipping.

- Recovery of mandibular impacted teeth (Fig. 6): When discovering an impacted tooth, if spontaneous eruption is not achieved in a timely manner by correcting the perceived cause, orthodontic guidance and/or surgical intervention may be indicated. In general, the recovery of impactions is a challenging problem with longterm ramifications. The use of the 3D lever arm, anchored by a MBS miniscrew, is particularly useful for dealing with severely impacted teeth. The SS lever arm can be adjusted

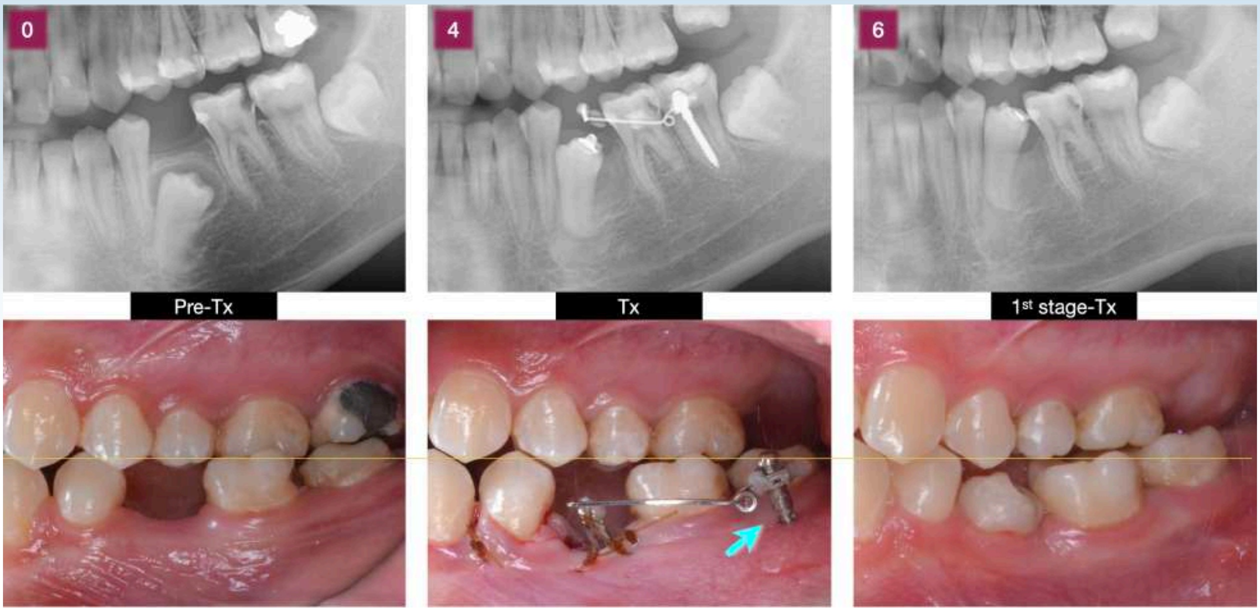


Fig. 6:
A six-image panel of clinical radiographs (upper) and photographs (lower) is divided into three columns marked with the months in treatment in the upper left area. Pre-Tx (0mo), Tx (4mo), and completion of first stage treatment (1st stage-Tx, 6mo). Alignment and finishing is accomplished with clear aligner therapy. The center panel shows the active mechanics for recovery of the impacted second premolar with a dilacerated root. Surgical removal of the impaction risks nerve damage, so orthodontic recovery with a MBS bone screw (blue arrow) anchored lever arm (0.019x0.025 SS wire) is an attractive option.

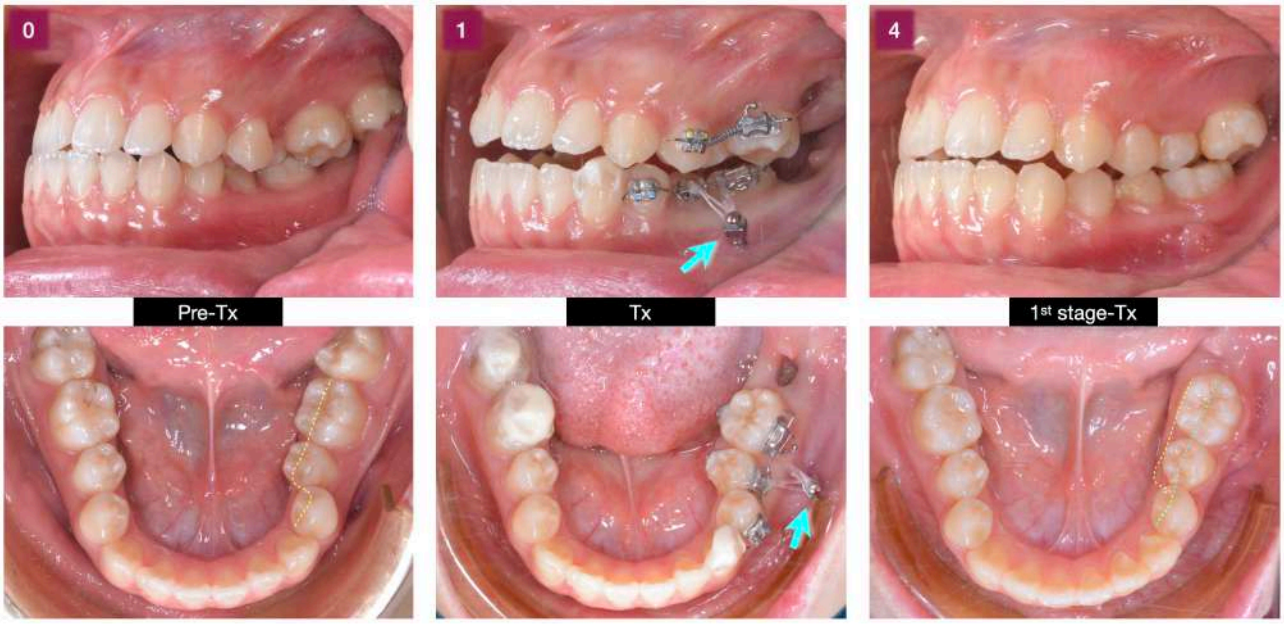


Fig. 7:
The correction of a full buccal cross-bite of the upper left first molar (UL6) is shown in a panel of six intraoral photographs. The month of treatment is marked in the upper left of each column depicting the Pre-Tx (0mo), Tx (1mo), and end of first stage treatment (4mo). The upper panel is a series of progressive left buccal views, and the lower panel is a corresponding series of lower occlusal photographs. The mechanics shown in the Tx column are occlusal bite turbos on the lower left first and second molars, and the elastics from the lower left second premolar and first molar are anchored with a MBS bone screw (blue arrows). The intermaxillary occlusion will be finished with clear aligner therapy.

for sequential movement in all planes of space without disturbing adjacent teeth

- Correction of lingually collapsed buccal segments (Fig. 7): Efficient treatment of full buccal cross-bite for an entire posterior segment (unilateral or bilateral) usually requires orthognathic surgery, bite-plates (turbos) and/or extensive use of TSADs in both arches. The preferred alternative for managing a unilateral scissors-bite is to reverse the etiology of excessive extrusion by opening the bite on the contralateral side with a glass ionomer bite turbo, then intruding and uprighting the teeth in crossbite with elastic modules anchored by a MBS miniscrew.

Acknowledgement

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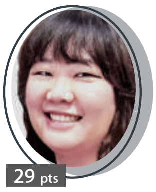

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